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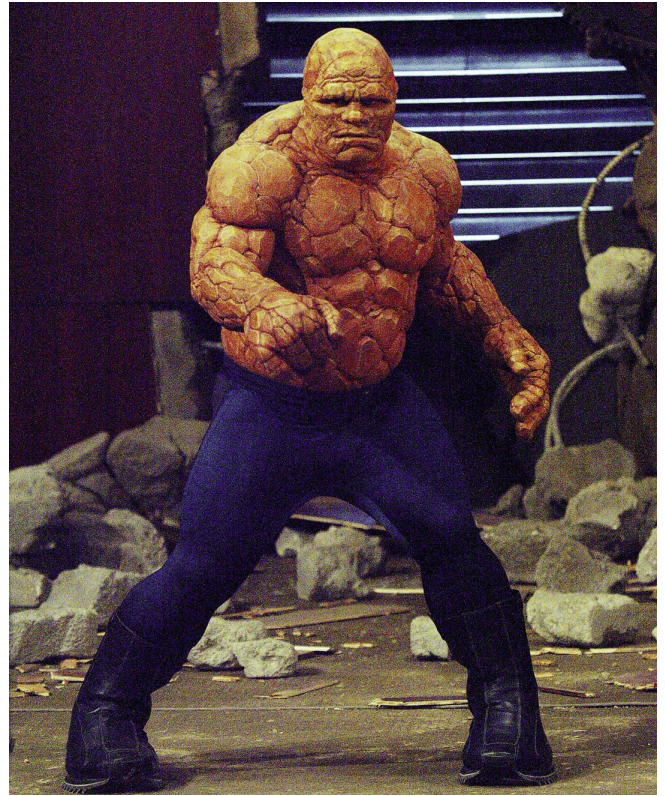
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Kurt Williams on *Fantastic Four*

article by Jody Duncan

Like many of his generation, visual effects supervisor Kurt Williams was familiar with Marvel Comics' *'Fantastic Four'* superheroes. He had childhood memories of his older brother reading the comic books, and he fondly recalled the *Fantastic Four* animated television series. Even so, Williams was hesitant about signing on when he was approached by Twentieth Century Fox and director Tim Story about the feature film. "I knew it was going to be a difficult show, because of the 'fantastic' characters. And I didn't know if I'd be able to put my own spin on it. But when I met with Tim Story, I found that he was extremely collaborative. So I jumped in, and we started figuring out how to bring these characters to life in a photoreal movie."



The story involves four astronauts who, while on a space mission, are exposed to cosmic rays that endow them with fantastic abilities. Reed Richards (Ioan Gruffudd) becomes Mr. Fantastic, capable of stretching his body to outrageous proportions. Susan Storm (Jessica Alba), as the *Invisible Woman*, can wrap herself in light and disappear. Ben Grimm (Michael Chiklis) transforms into the rock-like Thing. And Johnny Storm (Chris Evans) becomes the flaming Human Torch. Their nemesis, Doctor Doom (Julian McMahon), is similarly affected, and slowly transforms into a man of metal.

Working within a 15-month start-to-finish schedule, Williams conferred with Mike Elizalde of *Spectral Motion* — the company that would create physical character effects for the film — to determine what could be done practically and what would be assigned to CG. "We didn't have time to be fixing stuff at the last minute. So we divided up the workload specifically, right from the beginning. Visual effects would handle Johnny's flame effects, Reed's stretch effects and Sue's invisibility effects, and *Spectral Motion* would do Thing practically, with visual effects adding some enhancement to better integrate him into scenes." *Spectral Motion* also supplied metallic-looking prosthetics to simulate Doom's transformation.

Prior to the start of filming in Vancouver, Williams and Story agreed on an approach to the three characters that would be 'fantasticized' through computer graphics. "I promised Tim that he would be able to work with the actors on the set, and we would build our CG pipeline around that — meaning we would shoot the characters in situ, then roto out their performances and put the CG person over them. That not only got us our dailies right away — which was important, since we had only a 22-week postproduction schedule — it allowed Tim to work with the actors and have them involved in every scene."



Based on a series of Marvel comics, *Fantastic Four* — a Twentieth Century Fox production directed by Tim Story — involves four astronauts who develop supernatural abilities after being exposed to a cosmic storm in space. Visual effects supervisor Kurt Williams divided the show's 900 effects shots among a dozen vendors, including CIS Hollywood, which took responsibility for the early cosmic storm sequence. In addition to extending a partial interior space station set, CIS created digital cosmic rays and a full CG space station, integrating them with greenscreen elements of actor Michael Chiklis — as astronaut Ben Grimm — on a 'weightless' wire rig.



Cosmic ray exposure endows Reed Richards — as 'Mr. Fantastic' — with the ability to stretch his body to outrageous proportions. Soho VFX — which took on the Mr. Fantastic shots — started with a scan of actor Ioan Gruffudd's limbs to create stretching digital geometry, then tracked that to the actor. Soho artists used subsurface scattering shaders and attended to details such as cuticles and nail blush to create photorealism in closeups of the CG hand and arm .

Williams divided the show's 900 shots among a dozen visual effects vendors, hand-picking specific teams to concentrate on specific characters. Among his earliest discussions were those with the crew at Giant Killer Robots regarding the Human Torch. "One of the rules we set up for Johnny was that he burns from the core. It is so hot it doesn't necessarily burn at the skin level; it burns as it gets exposed to oxygen. Giant Killer Robots began the R&D for this in July, and we had a test of a CG human burning and beginning to fly by September." Final Human Torch effects fell into three categories, the most simple of which involved tracking practical flame elements to the actor. "Those were mainly for the beginning of the movie, where he is just learning to use his powers and the flames were relatively small in

frame. The second category was what we called the 'man on fire' technique, in which portions of his body emanated fire. For those shots, GKR produced fire simulations and attached them to specific body areas by doing a full 3D track of the actor in the scene. The idea was to pinpoint areas of fire, while still capturing Chris Evans' performance." The final category involved flying scenes, for which the production shot Evans against greenscreen. GKR composited those greenscreen elements into aerial plates shot in New York. GKR also produced CG New York environments not covered by the aerial photography, such as for a scene in which the Human Torch is chased by a heat-seeking missile. "We could get most of our aerial plates of Johnny above the city; but to get him down into the canyons of Manhattan, we had to do CG environments. We shot hundreds of photographs of New York buildings, from various points of the city, and GKR used those for textures in their 3D backgrounds."

Williams assigned Mr. Fantastic to Soho VFX, which tracked stretching CG geometry to the live-action character. Adhering to the production's overall effects philosophy, Soho obeyed basic rules of physics in creating the effects. "We didn't want to stretch Mr. Fantastic to the point where it was cartoony, so we laid down the rule that he would have some anatomical structure as he stretched. We also decided we weren't going to stretch out his skin to the point where it got transparent. Our conceit was that he actually generates new skin, and that's how he stretches — rather than just stretching out the skin he already has — and we built that right into the rig."

In one scene, Reed Richards reaches under a door of a quarantine facility, stretching his hand up to the knob to unlock it. "We put a lot of detail in that closeup of the CG hand — everything from cuticles on his nails to blush layers — and we used subsurface scattering to create the look of vascular layers beneath his skin. We began with a scan of Ioan Gruffudd's arm and hand, then we put it onto CG geometry, stretching the texture and the muscles underneath."

At the end of postproduction, with Soho's slate full, Kleiser-Walczak — which had executed the shape-shifting Mystique effects for *X-Men* — produced eight shots of Mr. Fantastic's face stretching



Stan Winston Digital rendered elements for invisibility effects and a force-field generated by the Invisible Woman (Jessica Alba), then effects artists at Hydraulx composited those elements into live-action plates.

as he converses with Sue Storm. Additional last-minute shot changes led to CafeFX doing five Mr. Fantastic shots for a climactic battle with Doctor Doom. “In this fight, Reed springs into the air and stretches out into a giant blanket to wrap around Doom. Since Soho had been using proprietary stuff, they just turned over their textures and their model, and CafeFX did their own cloth simulation.”

In designing the invisibility effect for Sue Storm, Williams referenced movies such as *Hollow Man* and *The League of Extraordinary Gentlemen*; but ultimately, the filmmakers opted to go in an entirely new direction. “This character was very beautiful — so why would we want her to disappear entirely, leaving nothing but walking clothes? Deciding it would be all right for the audience to see her a little bit, we created a form that we could dial in and out, depending on the scene.” A softer version of the classic *Predator* camouflage effect, the *Invisible Woman* form would be defined by its effect on the background. “We would warp the background, put a little lag on it through an offset, and that gave us her shape.” Stan Winston Digital created the effect. On the set, Story shot scenes both with and without Jessica Alba — the former to establish the character in the scene, and the latter to create clean plates with which SWD could rebuild occluded backgrounds seen through the invisible character. “They rotoscoped her performance, placed a CG version on top of it, then built several layers in the comp, so we could isolate her eyes, if we wanted, or any other feature Tim wanted to highlight. They also rebuilt her earrings and the backs of her clothing, tracking and compositing those in, as needed.”

The *Fantastic Four* first reveal their super-powers publicly during a rescue mission on the Brooklyn Bridge. Production replicated 200 feet of the bridge in a Vancouver parking lot, but relied on CG to create the full expanse of the structure. Running eight minutes and featuring more than 200 effects shots, the Brooklyn Bridge sequence was a stand-alone, mini-effects-movie requiring its own dedicated effects team. “Because 95 percent of the bridge in that sequence is CG, I needed somebody who would do nothing but create that environment. Meteor Studios had the pipeline established to do that.”

Additional work not directly related to the fantastic characters was farmed out to other vendors. CIS produced shots for the early space station sequence, in which the astronauts and Doom are exposed to the cosmic storm, digitally extending a small space station set and creating the cosmic rays. Pacific Title did compositing, and created CG buildings to more firmly set the film in New York. Pixel Magic also did compositing for a scene set on the Circle Line boat that cruises the New York harbor. “Ray McIntyre Jr. and I went to New York and shot plates from a boat. Then Pixel Magic integrated greenscreen material into those plates. They also added a CG wake for the boats and did sky replacements.” For a big scene at the end of the movie, Hydraulx generated six shots



Visual effects for Johnny Storm’s transformation into the ‘Human Torch’ went to Giant Killer Robots. For shots of Johnny initially exploring his pyrotechnic capabilities, GKR tracked practical flame elements to actor Chris Evans. Shots of Johnny in full-Torch mode, flying through city high-rise canyons, required GKR to composite greenscreen elements of Evans on wires into New York City aerial plates, enveloping the character in simulated flames. GKR

of Johnny creating a supernova to melt the metallic Doctor Doom. “We wanted Doom to have a slightly liquid look on the outside, but keep his form,

also created 3D New York environments for locations not covered in the aerial shoot.

because they quick-cool him and he turns into a statue at the end of the movie. Hydraulx put a CG version of Doom on top of Julian McMahon’s performance, and created layers of burnished, hot metal.” Rasha Shalaby of Cine-FN did five matte paintings for the movie, including a landscape of rolling hills for a scene in which Thing escapes the Doom compound, and a train yard below the Brooklyn Bridge, which was nestled into a New York plate. “We shot the plate in stills, because we didn’t have a motion picture camera. Then Rasha took our plate and created the train yard, animating a tugboat on the river and moving traffic.”

It took ten years for *Fantastic Four* to move out of development and onto the big screen; but, to Kurt Williams’ mind, the timing was perfect. “Now was the right time to make this movie, because technology had caught up to it. We were able to do Human Torch effects that looked good, and create a stretchy man that didn’t look like plastic. We were able to take the characters as they were drawn in the comics, and make them look real. That was our main objective — to stay true to the comic, but make it real. I think we did that. When you walk out of the movie, you’re going to say, ‘Yeah, that was the *Fantastic Four*.’”

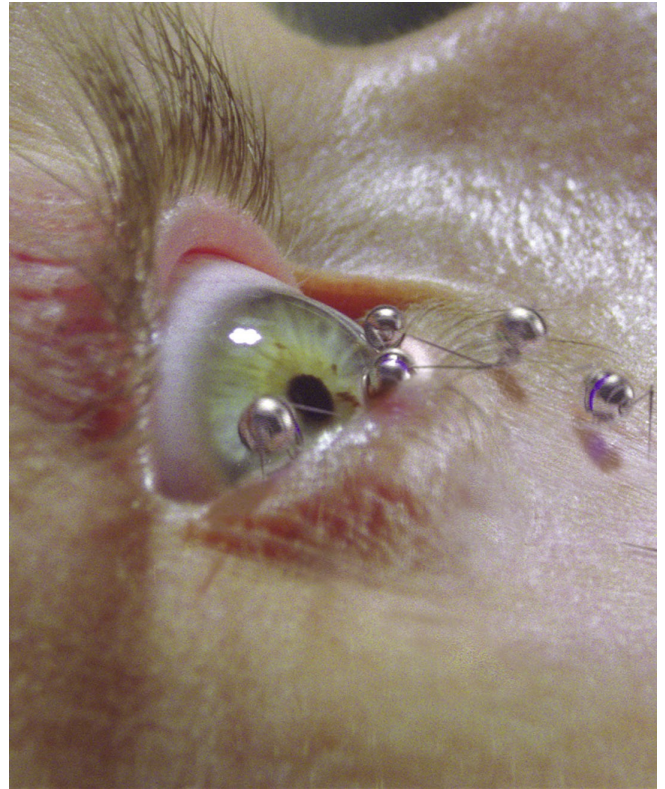
Fantastic Four photographs copyright © 2005 by Twentieth Century Fox.

Overview

Eric Brevig on The Island

article by Jody Duncan

The potential for abuse in human cloning is explored in *The Island*, a Warner Brothers/DreamWorks co-production directed by Michael Bay, with visual effects by Industrial Light & Magic and visual effects supervisor Eric Brevig. The movie is set in the year 2019, within a sterile, vaguely futuristic facility, in which behavior-controlled men and women are contained without access to the outside, contaminated world. The only clean spot left on the planet is 'the island,' where winners of a frequent lottery are sent to repopulate the earth. In truth, the facility's unknowing inhabitants are clones being raised by the Merrick Corporation for organ harvesting.



ILM digitally extended a massive facility set built at Downey Studios. For images of the island outside, crews shot plates in New Zealand, which ILM composited into bluescreen 'windows.' "Using Vistavision, our aerial cameraman shot six panels from two altitudes, at four times of day, at three locations. So we had a matching camera and lighting angle for virtually any shot — which was a good thing, because we see the New Zealand backgrounds in almost every shot in the facility."

Though many extras were filmed on the set, ILM added digital extras to fully populate the facility in wide shots. "We had generic bodies from ILM crew people who had been scanned over the years. Animation director Scott Benza and his animators created a library of motion capture behaviors — running, clapping, falling down. When the shots were cut together, if there was something special they didn't have in the motion capture, they would keyframe it."

The curiosity of one clone, Lincoln Six Echo (Ewan McGregor) leads him to restricted areas of the complex and, ultimately, the truth: There is no island, there is no contamination, and lottery winners are actually clones whose body parts are now needed by their real-world counterparts. Lincoln convinces his friend, Jordan Two Delta (Scarlett Johansson) to follow him in a run for their lives through the complex, into a series of maintenance rooms and tunnels, and finally outside to the real world.

Running on a catwalk within the complex, the pair discovers that the island views are only holographic projections. "This is a surprise for the audience, as well as a big reveal for the characters. The camera starts behind the characters, toward the scene outside. As they start running, the camera cranes up, looks down on them, then pops through to the other side of a

holographic screen at the same moment the characters pass through it.” A bluescreen into which the New Zealand plate photography would be inserted was positioned beyond where the hologram screen would be in final shots. “We just defined a point on the catwalk representing the holographic screen, telling the actors, ‘When you run past this point, you’re going to be in a new environment.’ We rehearsed it with the camera move, and eventually got the right timing. Then we layered in all the elements, starting with the New Zealand background. As they approached the screen, we teased in electronic images of the holographic screen; then, when we pop out the back side of it, they are standing within these big metal girders — and that was all CG. In the next shot, we go wider and see the entire hologram surrounding the complex, and these two tiny characters standing on the other side. That was all synthetic, as well, including the characters.”

The clones emerge from the underground complex onto a desert, shot near Las Vegas. Later, a trackless hover-train arrives at a train station, shot as a minimal set at the same middle-of-nowhere Nevada location. “All we had were stairs, a doorway and a little platform. We wound up replacing everything except the door they ran into with a fully digital set and train, because it was easier not to have to blend any live-action piece there.”

By train, Lincoln and Jordan arrive in near-future Los Angeles. “This was supposed to be about 15 years in the future, and things don’t change that much in 15 years; so we used the buildings that are there now, but added things to suggest the city is more built up.” Downtown L.A. combined plates shot there and in Detroit, with synthetic buildings creating the futuristic, built-up look. The visual effects crew did a data-capture session in Los Angeles, particularly on Grand Street, which served as the location for a pivotal chase sequence. “Using a tiling still rig, we shot all the buildings along that street, from the ground to the rooftop, as well as extended-range still material. Then we made CG versions of recognizable Los Angeles buildings, ‘futurizing’ them with a few details and sticking them into the backgrounds of the Detroit shots.” An aerial mass transportation system enhanced the city’s futuristic flavor. “We called them ‘wire buses,’ and they looked like something between a gondola and a monorail. They were an icon the audience could instantly identify as futuristic, and we put them everywhere in shots.” The wire buses were created through CG or digital matte techniques. “Our digimatte department has very sophisticated tools now that enable it to add 3D objects into scenes by doing a 2D matte painting onto a 3D shape, and then animating it. That allowed us to add these wire buses very quickly; and they looked as good as the 3D ones in the foreground.”



Industrial Light & Magic created effects for The Island, a DreamWorks production directed by Michael Bay, involving a society of clones, unaware that they are such, living in a highly controlled, antiseptic environment, isolated from a presumably contaminated outside world. After Lincoln Six Echo (Ewan McGregor) witnesses a botched surgical procedure and learns that he and others of his kind are being cultivated for organ harvesting, he and friend Jordan Two Delta (Scarlett Johansson), make a desperate bid to escape the complex. A shot revealing the pair emerging on the backside of a holographic screen – used by the clone-keepers to simulate views of a pristine island environment outside the facility – featured CG architecture, hologram screen, girders and characters.

Production shot many weeks on location capturing live-action footage for an extended chase sequence, as Jordan and Lincoln run from Merrick bounty hunters. The chase begins on a freeway where, having stowed away on the back of a truck transporting railroad-car wheels, Lincoln keeps his pursuers at bay by releasing the wheels one by one from the truck bed. “We had a real truck loaded with real wheels, which looked like giant barbells. But when we dropped a real one from the truck, it landed like a brick and stopped dead — instead of bouncing down the road and smashing into things, which is what we wanted. John Frazier made up fake ones that were heavy but not deadly, and Ewan pushed those off the back of the truck. A couple of them had rubberized material on them so they would actually bounce, but they were completely uncontrollable. So anytime you see one of these barbells near an actor or smashing into something, it was CG.” For a shot of a railway wheel demolishing a car hood, Frazier mounted a rig holding a practical barbell above the car. On cue, the physical effects team released the barbell, smashing it into the hood. ILM painted out the rig, animated a CG barbell that bounced toward the car and flipped onto it, then transitioned to the physical device at the moment of impact.

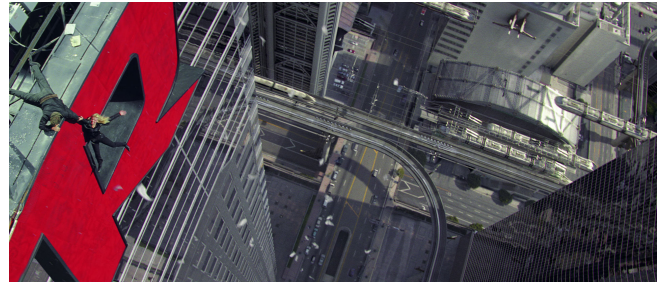
When ‘Wasp’ jetbikes join the freeway pursuit, Lincoln commandeers one from the bed of the truck. “He knocks the driver off the Wasp with a crowbar. Then the gunner flies into a freeway sign, which knocks him off. We shot a plate driving by a freeway sign, then animators animated a CG Wasp, CG falling driver and CG gunner looking up in surprise as he hits the sign.” Closeups of characters on the Wasps were achieved by shooting the actors against bluescreen, on a motion-base jetbike, or shooting stunt people on location, astride a Wasp hung from a marionette rig off the side of a truck. Other shots featured digital Wasps and digital characters.

The chase ends with Jordan and Lincoln taking cover inside a giant ‘R’ logo at the top of a skyscraper. “The ‘R’ was a set piece erected a few feet above the ground. We put that onto a building, surrounding it with Los Angeles architecture.” In the mayhem, the logo breaks loose from the side of the building, falling many stories to the ground below. “That was created as a single shot, looking up as the ‘R’ tips over, all the way to right before it hits bus-line wires and smashes into a construction site. The shot was CG, with some miniature elements. The ‘R’ was a 1/8-scale miniature, shot crashing into a same-scale building under construction. We also added a digital Lincoln and Jordan inside the ‘R’ as it fell.”



On the outside, Lincoln finds his real-world counterpart, Tom Lincoln, who has paid a fortune to have a clone ‘insurance policy.’ Visual effects supervisor Eric Brevig severely tested traditional twinning effects methodology – combining two motion control passes of a scene, one in which McGregor played against a stand-in, and a second in which the stand-in and McGregor switched roles – by staging scenes that featured close physical interaction between the two characters. For a scene in which Tom removes an ID bracelet from Lincoln’s wrist, ILM digitally attached the arm of the stand-in in the ‘A’ side of the shot to McGregor in the ‘B’ side, morphing the limb to adjust and improve alignment.

Surviving the fall, the clones locate the home of Lincoln's 'original,' Tom Lincoln. Scenes with Lincoln and Tom, both played by Ewan McGregor, were accomplished by shooting motion control of McGregor performing one character with a stand-in playing the other; then shooting the 'B' side, with McGregor and the stand-in switching parts. In post, the two sides were composited together. Though the twinning technique was not new, Brevig pushed the complexity of camera moves and twin interaction to their limits. In one shot, the two characters sit closely at a table as Tom removes an ID bracelet from Lincoln's wrist. "The physical interaction between them as Tom reaches over and takes Lincoln's wrist took many takes. I'd have to say, 'Okay, do it again — but this time, can you reach over half a second sooner?'" Despite the meticulous choreography, many shots required post touch-ups, such as painting in missing frames or 'digital surgery.' "For the transition from Ewan's arm to the double's arm, which happens on screen, we morphed his arm in one place and matched it up to the stand-in's arm. Half the time, it wasn't really Ewan's arm attached to his body, but you can't tell."



Running from corporate bounty hunters, Lincoln and Jordan wind up atop a Los Angeles high-rise. Due to the production's limited access to Los Angeles streets, most of the city locations were either live-action plates shot in Detroit or CG environments. To suggest the movie's 2019 time setting, ILM gave all of the city views a near-futuristic flavor by extending, rather than replacing, existing Los Angeles buildings and adding touches such as an aerial cable-car system. For shots of Jordan nearly falling from an 'R' logo atop the high-rise, crews shot the actor on a full-scale 'R' set, built just a few feet above the ground, then composited the live-action into the simulated L.A. setting.

At movie's end, Lincoln and Jordan make their way back inside the Merrick facility to destroy the holographic projection and reveal the outside world to the clone inhabitants. A fight between Lincoln and Dr. Merrick (Sean Bean) as Lincoln tries to shut down a generator was staged on a catwalk set, extended with a CG environment that included a massive generator fan. Shots of the fan falling as the facility begins to collapse used a 1/10-scale fan miniature. The film ends with the clones emerging from the facility, the camera pulling back to reveal hundreds of them — two-thirds of which were digital.

The effects for *The Island* stand on their own, but are especially impressive in light of the production's brief schedule. "We started shooting in October 2004, wrapped in March 2005, and delivered our last shot July 5. Given that schedule, we could have just as easily not delivered this movie in time — but, somehow, we did. We always do."

The Island photographs copyright © 2005 by Warner Brothers and DreamWorks.

Overview

Nick Davis on Charlie and the Chocolate Factory

article by Jody Duncan

When filmmakers convened to make the 1971 movie version of Roald Dahl's children's book, *Charlie and the Chocolate Factory* — renamed *Willy Wonka & the Chocolate Factory* — they had at their disposal only rudimentary photochemical effects tools. The invention of motion control was still several years away, and existing supercomputers were engaged in the serious business of putting men in space, not adding eye-candy spectacle to Hollywood movies.



In contrast, director Tim Burton enjoyed an embarrassment of visual effects riches as he launched into production of Warner Brothers' *Charlie and the Chocolate Factory*, starring Johnny Depp as the eccentric Willy Wonka. Able to realize anything the famously imaginative Burton could envision, the show's London-based effects teams — led by visual effects supervisor Nick Davis — helped to create a Charlie that was more magical and truer to the book than the earlier film.

Like the book, the movie tells the story of Charlie Bucket (Freddie Highmore), one of five children who finds a 'golden ticket' inside the wrapping of a Willy Wonka chocolate bar, thus winning a magical tour through Wonka's mysterious candy factory. Production designer Alex McDowell built massive sets at Shepperton and Pinewood Studios in England, but much of the environs would be realized as miniatures. "Tim knew he would have to use miniatures for big establishing shots. At the beginning, we worked out which shots we would be able to get on the sets, and which would require miniatures." Large town and factory miniatures, built by Cinesite UK, precisely matched the full-scale sets. "Alex McDowell is very computer-savvy; so, whenever possible, he designed his sets in Maya, and everything else flowed from that. Whether we were building virtual environments or miniatures, they were always based on these same Maya blueprints." More dynamic exterior sequences required virtual settings, which Cinesite created either as full CG sets or as 3D and 2½ matte paintings.

Factory interiors required CG augmentation, as well. In an early scene, the group tours the 'chocolate room,' then embarks on a boat ride through tunnels featuring a chocolate river and rapids. The chocolate room was a huge set constructed on the Bond stage at Pinewood, but the only way to do a dynamically moving chocolate river was as a virtual environment. "Working with Proof UK, we did previz to figure out the moves. Then we shot the actors in a boat on a gimbal, and integrated that into a CG chocolate river." The Moving Picture Company generated the shots. "MPC spent six months doing R&D on how to simulate chocolate. In reality, chocolate doesn't look that

good when it melts or when it pours. So we had to find a balance between what looked good and what looked real. MPC used a mixture of Real Flow and in-house software to create dynamic flow simulations.” Wide shots featured not only the CG environment, but also CG characters and CG boat. MPC matched the lighting on the gimbal boat, and used generic motion capture of performers on a smaller gimbal, being bounced around and swaying side to side, to animate the CG characters.

In addition to creating whimsical environments, visual effects helped to realize the Oompa Loompas, Wonka’s diminutive factory workers. In the 1971 film, the Oompa Loompas had been played by a handful of little people, but Burton was not inclined to use the same approach. “Tim wanted to use a single performer — Deep Roy — to play all the Oompa Loompas. Deep Roy is actually four-foot-two, but Tim wanted the Oompa Loompas to be two-foot-six. So we had one actor of the wrong height playing every Oompa Loompa in the movie!”

Davis and his crew shot Roy in repeat motion control passes — sometimes as many as 50 — against greenscreen or bluescreen, scaled the elements to the appropriate size, then composited them into live-action settings. “We couldn’t just clone a single performance, because these shots involved dynamic camera moves. Also, there’s a certain look you get when you clone something. You don’t get the slight variations that you do in repeat performances. Tim wanted the Oompa Loompas to be all the same, but still have some individual character — just enough so that it didn’t look like a cheap cloning trick.” In a few instances, crews shot Roy on a set, rather than on the process stage. “In the chocolate room, we were able to make certain areas of it look overscale just by adding a few set pieces and props. So we just shot Deep on that set.”

The most complex aspects of the Oompa Loompa shoot were the song-and-dance routines the characters would perform. Once composer Danny Elfman had delivered a particular song, a choreographer would work out the routine, and crews would videotape dancers performing the choreography. “From that videotape, Proof would do the previz, and that became our shooting bible. That was crucial because the shoot was so complicated. We had one performer basically dancing with himself, playing every single character in a dance routine that never had fewer than 40 Oompa Loompas on screen at a time.”



Warner Brothers’ *Charlie and the Chocolate Factory*, based on Roald Dahl’s 40-year-old children’s story, recounts the adventures of a group of children and their guardians as they tour the whimsical factory of candy-maker Willy Wonka (Johnny Depp). Director Tim Burton and visual effects supervisor Nick Davis relied on several London-based visual effects studios to realize the movie’s more magical elements — such as Wonka’s diminutive factory workers, called ‘Oompa Loompas.’ The Moving Picture Company created the Oompa Loompa effects, scaling down bluescreen elements of actor Deep Roy — who played all of them — and compositing them into CG environments or full-scale sets created by production designer Alex McDowell.

After shooting multiple passes of Roy for a full six months, the filmmakers conceded that a CG shortcut would have to be utilized. In fact, MPC had been developing a digital Oompa Loompa even as the repeat-pass shoot was in progress. “Tim was reticent about using CG Oompa Loompas in the beginning; but he quickly realized how time- and labor-intensive it was to shoot one guy with repeat passes, and how much more efficient it would be to use a CG character. The plan was to go to CG whenever the Oompa Loompa became one-quarter the size of the frame.” MPC most often animated the CG character using motion capture of Deep Roy. For shots in which Burton wanted to see more complex dance moves, production motion captured professional dancers. “We took that motion capture and retargeted it back onto Deep. That worked so well, we ended up seeing CG Oompa Loompas as large as half the frame.”



The tour group visits the ‘nut sorting room,’ a full-scale set that was populated with a mix of 50 real trained squirrels – shot separately in repeat passes to accommodate the animals’ preference for working solo – and computer generated squirrels, created by Framestore CFC. The Framestore CFC effects team wrote proprietary fur and skin shaders and paid meticulous attention to detail in producing its CG model to ensure the digital squirrel would intercut seamlessly with its live-action counterparts.

Neil Scanlan, who created the show’s animatronics and special makeup effects, supplied animatronic Oompa Loompas for backgrounds. “We used a lot of the animatronic Oompa Loompas for wide shots of the boat on the chocolate river. We attached their arms to the mechanical oars, so it looked as if they were rowing. We also used them on top of the cameras in the television room. They had a bit of head movement, and they worked extremely well.”

Though they would not be used, ultimately, animatronic techniques were explored for a nut-sorting room scene in which squirrels attack Veruca Salt (Julia Winter). Initially, Burton had hoped to achieve the entire sequence with real animals, shooting 50 trained squirrels on the set. “We were able to do some wonderful things with the real squirrels — such as shots of them shelling nuts — but they had a lot of limitations. They couldn’t do complex actions — such as when a squirrel taps a nut, listens, then throws it over his shoulder if he judges it to be bad. For those types of things, we built full-screen CG squirrels. They had to be absolutely photorealistic, so that they would intercut with the real squirrel live-action.” Framestore CFC executed the shots, building the CG squirrel and writing proprietary fur and skin shaders.

Toward movie’s end, Charlie and Grandpa Joe (David Kelley) join Wonka for an elevator ride, traveling through the factory, crashing through the roof, then flying over the English countryside. The elevator was either a practical gimbal set piece or CG. “A lot of it ended up being CG, because the elevator was glass, and there were problems of reflections on the stage. Half the time, we’d use the gimbal elevator purely as a way to contain the actors; then we’d strip it out and replace it with our CG box around them. Sometimes we also had CG characters inside the elevator.” The other problem with the gimbal elevator was that it could not be moved too dynamically, lest the children and elderly actors be harmed. “We had to put a lot of that movement into the shots in post, through digital trickery.”

Cinesite realized the sequence, creating miniatures for shots of the elevator flying over 'Fudge Mountain' and a hospital ward, and CG environments for other factory locations. "At one point, they fly through a room where the Oompa Loompas shoot guns firing candy, which explodes like fireworks. That was all CG — the fireworks, the guns, the Oompa Loompas and the elevator."



Cinesite contributed shots to a sequence in which Wonka, Charlie Bucket (Freddie Highmore) and Charlie's grandfather (David Kelley) take a magical elevator ride through the candy factory. To realize the sequence, Cinesite blended motion control elements of the actors aboard a gimbaled glass elevator set, shot against bluescreen, into miniature or CG settings, including the enormous Fudge Mountain. Some wide shots featured all computer generated elements — 3D elevator and animated characters within 3D environments.

While the London vendors realized most of the effects, Digital Domain created six shots of Violet Beauregard (Annasophia Robb) featured near the end of the film. Having been blown up into a giant blueberry earlier in the movie — an effect realized by MPC, using elements of Neal Scanlan's prosthetic face appliances projected onto a CG blueberry — Violet emerges from the factory squished back to her original size, but supernaturally flexible. "Violet does some incredible tumbl turns down the steps of the factory, stops and delivers a line of dialogue in an impossibly contorted position, then tumbles across the courtyard. We'd maxed-out our teams in London at this point, so we assigned these shots to Digital Domain." As a basis for the shots, Davis' crew scanned Robb and motion captured a contortionist performing acrobatic moves. "We delivered that to DD; then they built her body and animated her doing all the flips, using the motion capture only for reference." Digital Domain also realized shots of Mike Teavee (Jordan Fry) as an eight-foot-tall, inch-thick character — the result of his being attached to a taffy-stretching machine — working from cyberscans and motion capture of Fry and a very tall performer.

Charlie and the Chocolate Factory, greenlit at 350 effects shots, grew into a nearly 850-shot show. "Tim started the movie with one vision, but as he started to see what he could do with visual effects, he wanted more — and everybody was happy with the results. This movie is almost exactly the book. I didn't realize how identical they were until I finished the show, got home, and started reading the book to my son. That book really is the movie we made."

Charlie and the Chocolate Factory photographs copyright © 2005 by Warner Brothers.

Overview

John Van Vliet on Herbie: Fully Loaded

Article by Estelle Shay

The old W.C. Fields adage — ‘never work with children or animals’ — might have been expanded to include cars, had Fields been around when Walt Disney Pictures had the idea of imbuing a Volkswagen Beetle named Herbie with a mind of its own in the 1968 comedy, *The Love Bug*. With its clever conceit and charming effects, *The Love Bug* paved the way for three sequels over the ensuing decade, plus a television remake of the original film. Even today, *Internet* websites attest to a devoted fan base of Herbie-philes who collect the cars and gather for *Herbie Love Bug* Reunions.



No surprise, then, that Disney would decide to resurrect Herbie and introduce him to twenty-first-century audiences. In an all-new installment, *Herbie: Fully Loaded*, the indestructible #53 is rescued from a junkyard by Maggie Peyton (Lindsay Lohan), a third-generation member of a NASCAR family, and once again finds himself in the midst of high-octane action — this time in a series of races leading to a big-league NASCAR competition.

Four months before the start of principal photography, with a still-evolving script in hand, director Angela Robinson recruited John Van Vliet to oversee visual effects for the production. Van Vliet began by assembling a previz team to define the scope of the work and to rough out shots. “As it turned out, that was probably one of the smartest things we did. I had Bill Arance, Chad Cole and Doug Beswick taking whatever the storyboard guys handed us and turning it into animated sequences. We generated as much previz as we could, even coverage of shots we didn’t think were going to need effects. The guys were such great animators, a lot of the shots that ended up in the show are amazingly similar to the animatics.”

An obvious concern was how to impart personality to a car. “One reason we came on the show so early was to develop character performance rules for Herbie. Through animatics and stills and sketches, we created an entire manual on the different things Herbie could do. There were some factions in the studio system who wanted to see Herbie do everything but smoke a cigar and do standup jokes. But Angela’s instincts were very good, and she pulled it back. What we ended up with was fairly subtle. We determined that most of Herbie’s emotions would be conveyed by his headlights and bumper. I was pleasantly surprised by how much nuance we got out of just a slight headlight rotation and a quick blink with the visor.”

Animatics covered the various permutations of Herbie, who, in the course of the movie goes from an old abandoned junkyard car to a spiffed-up version dubbed 'Pimp Herbie,' to a battered 'Demo Derby Herbie,' and, finally, to 'NASCAR Herbie.' Approved Herbie designs were handed off to special effects supervisor Matt Sweeney and his crew, who constructed a full-size mechanical car, dubbed 'Personality Herbie,' for puppeteering on the live-action set. Equipped with radio controls and hydraulics, the mechanical car had pivoting bumpers, a body that could rattle and shake, antennae that wiggled and headlights that rotated and blinked, with little visors designed to fold down over the 'eye' like a big eyelid. This master car was redressed for each variation of Herbie.

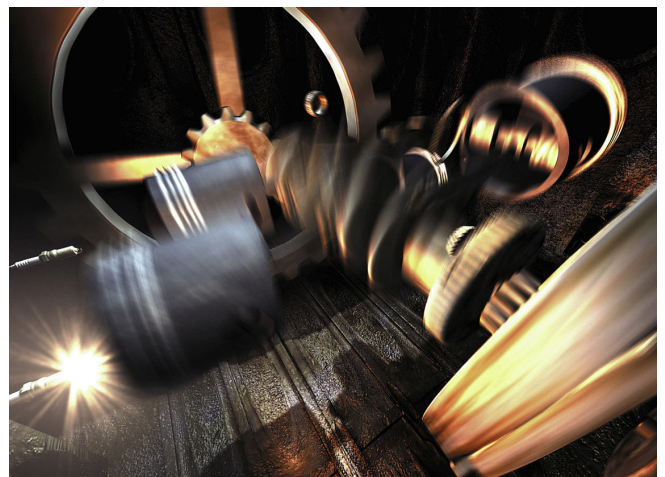
As shooting got underway in August 2004, Van Vliet lobbied to have Robert Short brought onboard as supervising puppeteer for the mechanical car. "We discovered early on that we needed to have a point man for Herbie's performance, to give it a little more focus. Basically, Bob had my dream job — working with the guys who puppeteered the car, taking all the stuff we had designed and bringing it full circle through the actual shoot."

Personality Herbie could carry the effects only so far, though. "Matt's car had more radio control and linkage equipment than a stealth bomber, but there was no room for an engine, or anything that could make it actually run. So any time you see Herbie driving and doing his performance thing, we had to pull the bumper off and animate a CG replacement, or track in CG headlights on top of the real ones." Entity FX, one of several postproduction houses assigned to the show, completed 40 to 50 replacement shots and built prototype 3D models of Herbie and other NASCARs for use by all the vendors.

Production's original plan to achieve as much as possible with physical effects and stunt work proved overly optimistic; and so the volume of shots requiring effects intervention grew as filming progressed and the editing process began. "We tried to get plate coverage on anything that was pushing the envelope in case we needed to go back and rework it in post. Fortunately, I had a guy — Bill Kent — with second unit, documenting everything and making sure we got good coverage. I figured that almost anything that had to do with race footage and actors in cars would have to be shot on a



In revisiting its classic Love Bug franchise with Herbie: Fully Loaded, Walt Disney Pictures enlisted visual effects supervisor John Van Vliet to orchestrate the production of some 650 visual effects shots contributed by seven vendors. Rescued from a junkyard by Maggie Peyton (Lindsay Lohan), the Volkswagen Beetle with a mind of its own shakes off water after being washed. Special effects coordinator Matt Sweeney's team installed a shaker unit under the car. Then, during post, the shake speed was increased — with the actors split-screened so that their movements would stay normal-speed — and CG water spray was added by CIS Hollywood, which also provided most of the film's greenscreen composites.



To establish the bond between Maggie and Herbie at the start of their first street race together, the camera passes from Maggie's hand on the gear shift, through The Love Bug's rickety engine and transmission, and out the exhaust pipe. Hammerhead Productions animated the

greenscreen stage and comped into plate photography — which proved to be true.”

When Herbie's opponent attempts to sideswipe him, the Furious VW pops a wheelie to avoid being hit, going completely vertical and sliding down the street on its rear bumper. Make Inc. integrated a fully-CG Herbie into live-action plate photography of the second car.

Greenscreen composites were, in fact, a principal component of the effects work, the bulk of them done by CIS Hollywood. Other vendors on the show were Industrial Light & Magic, which tackled a number of complex all-CG shots in the NASCAR race, Make Inc., responsible for several fully CG shots of Herbie performing backward wheelies in a desert race, Pixel Magic, assigned an effect called ‘Herbie Vision,’ and Hammerhead, which contributed two shots moving through Herbie’s engine and transmission in a nod to *The Fast and the Furious*.

The desert race, in which Maggie competes against racing superstar Trip Murphy (Matt Dillon), was to have been shot at the El Mirage dry lake bed in the Mojave. “The race is supposed to be out in the middle of nowhere, and there were going to be shots where we’d be seeing great vistas, with the lead actors standing out there lonesome against this vast expanse. Unfortunately, due to an overambitious schedule, the main talent never got to El Mirage — just second unit with the cars and the extras.”

Production opted for the actors to be shot greenscreen — at another location set erected at Hansen Dam in the San Fernando Valley — and composited into El Mirage plate photography. Since no preparations had been made for greenscreen at Hansen Dam, physical effects and camera crews scrambled to make do with what they had. “Mike Anderson, who was the key grip and knew more about hanging greenscreen than anyone I know, stepped up to the plate and said, ‘We can do this.’ He hung what little greenscreen we had — it looked like a giant, patched-together quilt — and we moved it around as best we could, trying to stage all the actors in that one little coverage area.”

CIS was given the unenviable task of assembling the composites. “It was the first time I’ve ever walked into a place with shots in hand and apologized right from the get-go. Some of those shots were just hideously bad! But it was one of those situations where you run with what you’ve got. Mike did what he could at Hansen Dam, Bill got some really good plates out at El Mirage, and Tom Smith’s crew at CIS was able to somehow extract mattes, track all the camera moves, balance everything, colorize it, patch it together and make it work. It’s probably the most astonishing piece in the show, because you look at it and you’d never know we weren’t there.”

Of all the action sequences, the NASCAR race, in which Herbie engages in a comical, no-holds-barred face-off with Trip Murphy, the circuit champion, served up the film’s most interesting effects challenges. “Take the Ben-Hur chariot race and Black Stallion, put them together, add a dash of *It’s a Mad, Mad, Mad, Mad World*, and you’ve got our NASCAR race.” The strategy for the sequence involved dropping a CG Herbie into race footage captured at an actual NASCAR event. “Disney convinced NASCAR to let us put a real Herbie out there on the track and do a lap with the warm-up guys just before the real race started. So we had our car physically there for a bit, which was a huge bonus.”

Given the unpredictability of the setup and the lack of race specifics in the script, Van Vliet determined that the best approach would be to capture race footage that allowed for the creation of a virtual set. “First unit covered the front section around the stands and anything having to do with tracking the real car or people, and we covered the backgrounds — the massive crowd scenes.” Dynamic footage of the stadium was obtained just before the start of the race by running a camera car equipped with a 7-camera Circlevision rig around the track at 80 to 100 miles per hour. “We did a full lap, and the footage we got from that allowed us to create a virtual bubble that we could stitch together for views of people in the stands from almost any angle. We discovered, though, that the stadium doesn’t actually fill with people until moments before the race. Everyone stays under the stands drinking beer, because it’s really hot out there and there’s nothing more boring than sitting around watching nothing happen. Just a couple of minutes before the race starts, they all come out. So our time window for shooting the full crowd was very tiny.”



Industrial Light & Magic was engaged late in postproduction to provide some especially complex shots during the final big race, shot on location at the California Speedway in conjunction with an actual NASCAR event. In order to avoid being drawn into an unfolding accident, Herbie drives up onto the track-side safety fence to pass over another car. A shot of the camera passing through the fence and panning to follow the action was almost entirely CG, with only the far background view of the pits and the people behind the fence being real. In three of the ILM shots, the setting was created entirely from still photos taken at the actual race.

In postproduction, the NASCAR race with Herbie in it was pieced together using a bag of tricks that included 2D compositing, stitched-together moving backgrounds, and considerable 3D effects. ILM, under visual effects supervisor Jeff Olson and animation supervisor Kim Libreri, took on the bulk of the 3D work, creating some 22 shots, including three that were fabricated entirely from stills captured at the real NASCAR event.

By the end of postproduction, the visual effects for Herbie had ballooned to some 650 shots, keeping Van Vliet, whose early career had included a stint at Disney as an animator, occupied for more than a year. “Years ago, when I first worked at Disney, there was a running joke that if you ever worked on a Herbie remake, your career was probably over. So when I first got offered this film, I thought: ‘This is like a bad joke coming back to bite me in the butt!’ But foolish enthusiasm and a desire to play with cars triumphed over good sense, and I took the show anyway. As it turned out, it was a really good experience. And what could be more fun than throwing Volkswagens around?”

Herbie: Fully Loaded photographs copyright © 2005 by Disney Enterprises.

ARTICLE BY JODY DUNCAN

When producer Laura Ziskin first contacted director Rob Cohen regarding *Stealth* — a project she had been developing with Mike Medavoy — she presented him with a good news/bad news scenario. The good news was that the screenplay by W.D. Richter, involving a futuristic, computer-controlled drone fighter jet, had an intriguing storyline, as well as some of the most dynamic aerial sequences ever conceived. The bad news was that Ziskin did not know if realizing those aero-technics on film was even remotely possible.

Cohen accepted the challenge, intrigued by the story's central themes concerning war and technology. "This movie explores some very interesting questions," said Cohen, "such as: Is the human element in war critical? Do we need bodybags to put a check on war? If we can just send in drone fighter planes, without having to worry about casualties, are we more likely to go to war just because we don't like what somebody said about us? The Navy has announced that by 2011, one third of the jets in the Naval Air Force will be unpiloted. By 2025, they expect that the entire Naval Air Force will be pilot-less. So this is happening, and this movie was an opportunity to talk about it." On a more visceral level, the movie had potential as a thrilling display of sheer speed, a phenomenon Cohen had explored in previous films, such as *The Fast and the Furious* and *XXX*. "These jets move faster than anything else on earth; and so *Stealth* was the natural ultimate project to follow my last couple of movies. I jumped in with both feet and hands."

Despite his enthusiasm, Cohen recognized that the screenplay presented enormous challenges. More than half of the story took place in the air, with solo pilots in cockpits talking via headsets — not the most dynamic scenario for actors or an audience. Secondly, the stealth bombers that were essentially the stars of the movie did not, in reality, exist. "These jets were much more advanced than what we have now," Cohen said. "That meant we had to design jets, build them, and somehow make them fly."

Beyond just straightforward flying, however, these jets would perform extraordinary maneuvers — continuous barrel rolls, extreme banking moves, rocketing between narrow canyon walls — throughout the film's aerial sequences. Cohen upped the ante with camera movement that would be just as dynamic and unrestrained, the camera jumping from the upper atmosphere to a cockpit closeup, or traveling through the interior of a jet engine. "I wanted the audience to experience speed and flight in the first person," Cohen commented, "not in the third person. I also wanted the camera to change its perspective radically, so that we might start out in outer space, looking at a spy satellite, but then jump on to the laser reader of that satellite, ride it down to earth, find a country, find the airplanes and wind up in the cockpit of one of those planes — all in one shot. Or the camera would swing outside the plane, into the cockpit, then down the pilot's arm, through the guts of the plane, into the missile bay and onto the missile, taking on the missile's POV as it travels toward the target. These were the kinds of things I dreamt of, but didn't quite know how to do. No one knew."

The only way to achieve such radical aerial and camera maneuvers was to go with a digital approach, compositing animated CG jets into aerial plates or CG environments. To illustrate the dynamic style he had in mind, Cohen commissioned Digital Domain — his longtime visual effects collaborator — to create a 40-second video test shot, an assignment led by visual effects supervisor Joel Hynek, with whom Cohen had worked closely on XXX. “It was a shot of a pilot shooting a missile at a desert location,” said Hynek, “with the camera moving in a way that really made you feel as if you were flying and were part of it. Having been a pilot for 30 years, I was very excited about doing shots that would express the experience of flying.”

In addition to demonstrating the movie’s camera style, the test shot explored whether or not photorealism could be maintained throughout the 50 minutes of full 3D that would result from the digital approach. “Intuitively, we understand the physics of earth,” said Cohen. “We understand force, momentum, acceleration, the law of inverse squares, equal and opposite reactions. We understand all of that from the world we observe. Would an audience believe they were watching real jets and real pilots inside those jets throughout all of those 50 minutes of CG? That was another question we had to answer.”

Based on the strength of the test, the film earned a greenlight from Columbia Pictures late in 2002, at which time Cohen and a small Digital Domain crew launched into previz, creating animatics for half of the anticipated 800 effects shots. Other preproduction tasks included designing the aircraft: the Talon, the swing-wing stealth bomber flown by the main pilot characters, and the Extreme Deep *Invader*, or ‘Eddie,’ the experimental unmanned combat aerial vehicle — UCAV. Though both jets would be futuristic in design, capable of flying at speeds up to Mach 5 within the context of the story, Cohen sought authenticity by inviting two designers from the Northrop Grumman global defense company to join the production design team for a period of three months. At the end of that three-month process, the designers had produced jet concepts which — to Cohen’s cinematic mind — looked too similar to already existing aircraft. “The designers said, ‘Well, the nature of aerodynamics is constant, so if you want these jets to do these sets of things, this is what they’ve got to look like,’” recalled Cohen. “I explained to them that this was the movies, not real life, and that the jets didn’t got to do anything except be cool.”

Cohen tasked production designer J. Michael Riva and a new team of industrial designers with ‘sexing up’ the jet designs, while maintaining their aerodynamic integrity. “We spent another three months really going out there with these designs,” Cohen remarked, “keeping in mind all the things they would have to do in the picture. They had to have swing wings. They had to be hypersonic. They had to carry missiles and bombs. They had to dogfight. They had to take off from an aircraft carrier and land. And they had to have a very low profile.” Most of all, they had to be cool. In fact, Cohen used the term ‘gamer cool’ to describe his overall aesthetic for the movie. “Gamer cool meant that a kid who is a computer game fanatic would look at every aspect of this movie and think, ‘I don’t want to just watch this movie — I want to play it!’”

Though the Talons and Eddie would be computer generated in all of the aerial sequences, production constructed full-scale mockups for shots of the planes parked on runways or on the deck of an aircraft carrier. “I thought it would be a good thing to have something really there in scenes where support units were refueling a jet or it was being towed on the deck of the carrier,” noted Cohen. “It would give the actors a sense of the plane’s mass and scale, and it would give the visual effects guys something real to match to.”



Stealth, the latest high-speed action picture from director RobCohen, showcases the technical aspects of unmanned, computer-controlled military aircraft, while also exploring potential ethical dilemmas involved in their use. Featuring extremely dynamic aerial sequences, the movie presented myriad filmmaking challenges. Fictional warplanes – both the Extreme Deep Invader drone, dubbed ‘Eddie,’ and the manned ‘Talon’ stealth bombers – had to be designed and realized on screen in conjunction with outrageous jet and camera maneuvers that required backgrounds impossible to capture via traditional aerial photography. Digital Domain – with visual effects supervisor Joel Hynek at the helm – met those challenges through both established and innovative effects techniques.

Determining that the lines of the Talons and Eddie were more ship-like than anything else, Cohen hired Australian boat-builders to construct the full-scale aircraft at Fox Studios Australia, where production was based throughout most of its 88-day shooting schedule. In addition to interior sets, the production setup in Sydney included one massive greenscreen stage, on which sat an elaborate hydraulic gimbal, built by special effects supervisor John Frazier and his team to enable Cohen to shoot his actors in dynamically moving cockpits. “A huge chunk of my movie was going to feature pilots sitting in a chair with a little stick between their legs,” Cohen observed. “Making that interesting and compelling was one of the big directorial problems. So I told Frazier that I needed a gimbal that could do unprecedented things.”

Frazier complied, building a 70-ton gimbal that could pull nearly 5g’s of force while moving on multiple axes. “The gimbal could point up and down 90 degrees,” said Joel Hynek. “It could yaw 30 degrees, left and right; and it could rotate continuously, completing a 360-roll in only two seconds.” Mounted to the gimbal was an approximately 20-foot section of the nearly 70-foot-long Talon — the nose, the cockpit in which the actors would sit, and a three-foot section behind the cockpit — although, in final shots, much of that jet body would be replaced with a CG model tracked to the moving cockpit. The entire Talon/ gimbal rig was erected to a height of 20 feet on Fox’s largest stage to accommodate the extreme-angled pitch, yaw and roll moves.

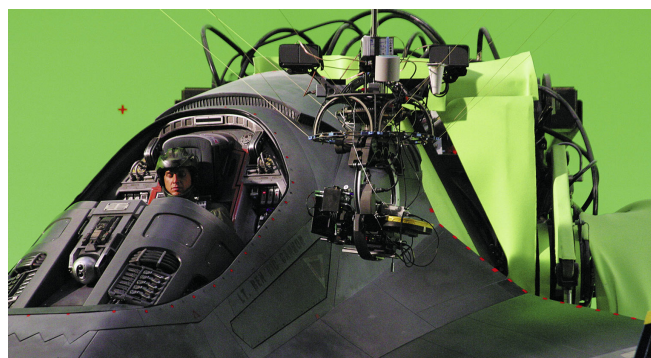
Over the course of 35 days on the greenscreen stage, actors Josh Lucas, Jessica Biel and Jamie Foxx — who portrayed pilots Ben Gannon, Kara Wade and Henry Purcell, respectively — spent hundreds of hours inside the wildly articulated cockpit, with Cohen showing little mercy as he captured the most dynamic footage possible. “Rob really bounced the actors around in that thing,” remarked Hynek. “The continuous rolls he put them through especially made them sick. We’d put a camera in there with them, with a wide-angle 20mm anamorphic lens on a snorkel, so you’d see them reacting to the forces of gravity as we rotated the cockpit.”

Outside the cockpit, crews filmed the gimbal action with a Spydercam to execute the complex, multi-axis shots illustrated in the previz. Going into production, the plan was to load those previz

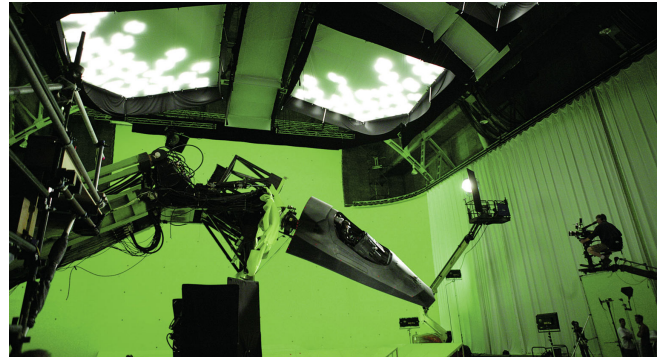
files into a Kuper motion control system to drive both the gimbal and the camera, simultaneously. “We first had to make sure all the rates we were asking the camera and the gimbal to do in the previz were attainable on stage,” recalled Hynek. “Often we had to change a shot somewhat — maybe the Spydercam couldn’t move 40 feet per second, as the shot was set up in the previz, or maybe the gimbal couldn’t move fast enough. Having one computer drive a Spydercam and a gimbal, all slaved to the previz, was something that had never been done before; so it took a great deal of coordination — but when it worked, it worked really well.”

Most often, the gimbal was operated via a more spontaneous, hands-on method, with real Navy jet pilots — military advisors on the show — sitting at a control unit on the floor of the stage. “Through that control unit,” said Cohen, “the pilots could essentially ‘fly’ the plane on the gimbal. It looked like an elaborate go-cart with rudders, a stick and all of the other controls to make the gimbal do anything we wanted. I’d be standing over the pilots at this thing, saying, ‘Okay, we’re over a mountain range at 10,000 feet, there’s this kind of air chop, and I want the plane to do this or that.’”

Director of photography Dean Semler designed and executed a lighting scheme for each sequence on the greenscreen stage, which was then matched, to the degree possible, in Vistavision aerial plates that would provide many of the backgrounds for the cockpit footage. “Usually,” noted Hynek, “you shoot your backgrounds first and then shoot your greenscreen. In this case, we shot the greenscreen first, basing it on an agreed-upon general lighting scheme that Rob, Dean and I had worked out. Then we could shoot aerial backgrounds that matched that lighting.” Hynek shot the aerial plates himself, either from a helicopter or a Lear jet, depending on the sequence. “We probably shot more from the helicopter than the Lear jet, just because it was more versatile. But the Lear was important for the cloud work, because we needed more height and speed than we could get from the helicopter. We usually shot around three frames per second, and then often sped that up by a factor of two or more.”



Housed at Fox Studios Australia in Sydney, the production set up one greenscreen stage solely for the purpose of filming actors Josh Lucas, Jessica Biel and Jamie Foxx— as pilots Ben Gannon, Kara Wade and Henry Purcell — inside Talon cockpits. To make the footage as visceral and dynamic as possible, special effects supervisor John Frazier attached a partial Talon mockup to a gimbal capable of executing extreme pitch, yaw and rotation moves at high speeds. Cohen heightened the drama by shooting wild camera moves via a multi-axis Spydercam.



Joel Hynek and his stage crew imported previz files to drive the Spydercam and the gimbal rigs simultaneously – thus slaving all the camera movement and cockpit gyration to production-approved animatics. While the technique worked for a number of shots, Rob Cohen came to prefer a more spontaneous, hands-on approach, directing real Navy jet pilots as they operated a waldo-like unit – complete with rudder and stick controls – to essentially ‘fly’ the gimbaled Talon on stage. Director of photography Dean Semler set up articulated lighting rigs to cast alternating light and shadow on the actors’ faces, simulating clouds whipping by the fast-moving aircraft.

Given the speeds at which the fictional planes would be flying, and the wild aerial stunts Cohen envisioned, plates alone could not provide all of the necessary backgrounds. “When you say you’re moving Mach 5,” Cohen remarked, “there’s nothing — including speeding up and frame dropping — that is going to move a plate that fast. And there’s not an airplane, jet or helicopter that can do what these jets can do. So how do you get these environments? How do you get these moves? Another consideration was the amount of footage we needed. This film travels to 13 countries, at speeds way beyond the norm, which meant we needed thousands of miles of various types of terrain. Shooting plates for all of that, even if we’d been able to get the kinds of plates we needed, would have been impractical and prohibitively expensive.”

To create backgrounds that could not be captured in plates, terrain lead Brad Herman refined a digital environments tool — EnGen — that Digital Domain had first developed for the snowy landscapes in *The Day After Tomorrow*. “EnGen allows you to create terrain that is based on USGS digital elevation map data of any location in the world,” Hynek explained. “It has hundreds of procedural rules that it applies to that basic map to make the terrain look just as it does in that real



For scenes on the USS Carl Vinson— the aircraft carrier to which Ben, Kara and Henry are assigned – the production gained permission from the U.S. Navy to shoot on board a real seabound aircraft carrier, the USS Abraham Lincoln. Though the Talons were most often computer generated, production commissioned boat-builders in Australia to construct a full-scale practical version, then transported it to the Abraham Lincoln— the first time the Navy had ever allowed an unofficial aircraft on board a carrier. A CG Talon prepares to take off from the carrier deck while, in the background, crews attend to the full-scale mockup.

place. Where does the snow line start? Where is the vegetation, based on the gradients of slopes? Where are the rocks? What kinds of rocks are there? How much rubble should there be at the base of this particular slope? EnGen determines all of that, based on this set of procedural rules. We could even add things, such as roads. We could say, 'I want a road that goes from point A to point B,' and EnGen would decide where the road should go in between those points, based on the topography. It would shave a little bit away from the up-slope side of the mountain and fill in the little berm — just like construction crews would really do if they were building a road on that mountain. The only thing EnGen couldn't do was trees; so we created 3D trees in Houdini and just comped them in." Crews often added hand-sculpted or painted detail, such as distant roads or rivers, to the EnGen terrain, to help the scale or to make it more closely match an existing, intercutting aerial plate.

Endowed with physically based atmospheric calculations, EnGen could also produce very naturalistic atmospheric effects such as hazing out a horizon mountain range or changing its color to indicate distance and angle. Other atmospheric effects were created in service to one of Cohen's key directives: the aircraft always had to be moving through something and in resistance to something, as opposed to flying through a virtual, empty space. "Rob really wanted these planes to look as if they were slicing through something physical," recalled digital effects supervisor Kelly Port. "That meant that we had to create a visual representation of the atmosphere. We did that through wingtip vortices, lift condensation, heat distortion, haze, clouds, exhaust — anything we could think of to make the airplanes look as if they were interacting with something. If you just have a plane flying past a blue background, you have no sense of how fast it is moving. We always had to have a visible atmosphere to create a sense of interaction and enormous speed."

Speed was the show's central concern; and to simulate it, Digital Domain and Cohen designed shots in which terrain and clouds would move very fast in frame, close to the sides of the planes or reflecting in the pilots' visors and cockpit canopies. Parallax and depth were also vital to creating a sense of speed. "Rob always wanted these shots to have a foreground, a midground and a background," said Hynek. "Even if the planes were just in the clouds, we would do background, midground and foreground clouds to get a good parallax going." Effects animator Cody Harrington and technical director Josh Krall used 'Storm' — the proprietary volumetric rendering software for which Digital Domain had won a technical Academy Award — to generate a library of highly detailed, realistic CG clouds.

Stealth opens ten miles above the earth, the camera moving from the clouds in the Columbia Pictures logo to photography of real clouds — shot from a Lear jet — to a combination of real and CG clouds. The clouds open to reveal three Talons, piloted by Ben, Kara and Henry. "Rob wanted



Eddie hovers over the carrier deck. Like the Talons, Eddie was a digital creation in all but a few ground shots. Production hired aircraft designers from Northrop Grumman to lend verisimilitude to the fictional jet designs, then brought in industrial designers to 'sex up' the concepts to Hollywood movie standards. Digital Domain built its CG aircraft models from art department blueprints, then developed a shader/compositing technique to give artists control of the lighting on the aircraft without repeated rendering.

everything to be somewhat mysterious at this point,” said Hynek, “so we put a lot of reflections on their helmet visors and on the cockpit canopies to obscure the characters a bit.” CG visors and canopies would be tracked to the majority of the aerial shots, as most of the gimbal material had been shot without either. “There was a big debate at the beginning as to whether we should have practical canopies on the gimbal when we were shooting; and they built some, just to see what they would look like. But of course, when the canopy was on the cockpit, it reflected every light on the stage, so we immediately abandoned that idea. Rob still wanted to shoot with the visors as much as possible; but, again, they would reflect the stage lights. Rob’s attitude was ‘I don’t care’ — but we always preferred that the visors not be there, and in the majority of the shots, they weren’t. Most of the visors are CG.” A dedicated ‘visor and canopy’ team tracked the CG elements to the cockpit footage for hundreds of shots, integrating them into scenes with the addition of dirt effects and fast-moving cloud or terrain reflections.

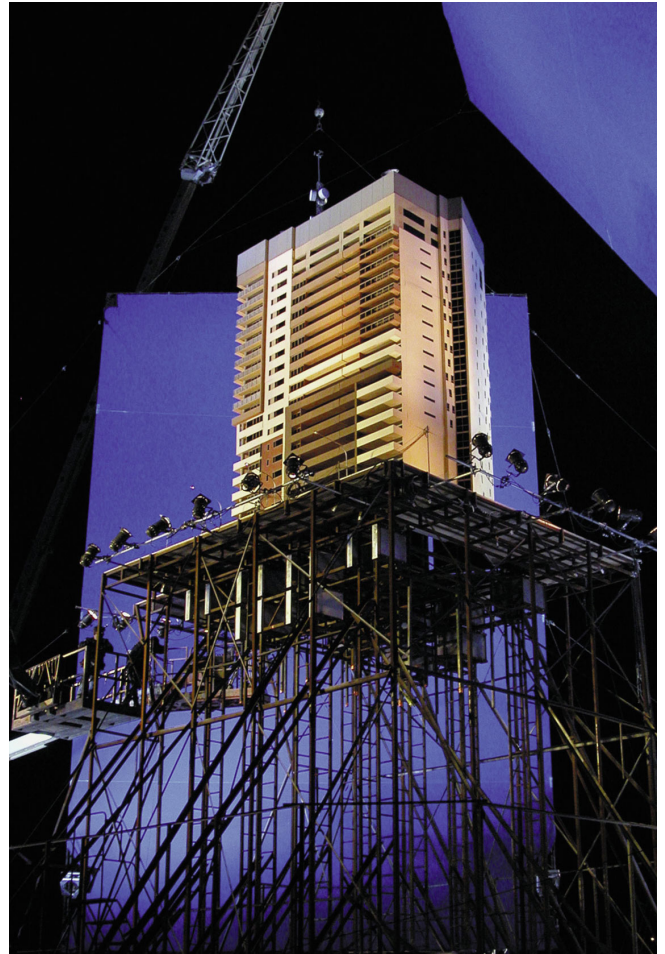


On orders to destroy a terrorist cell convening in a Rangoon high-rise, Ben executes a vertical dive and drops an implosion bomb onto the building’s rooftop. Joel Hynek shot aerial plates from a helicopter in Bangkok, Thailand, for the sequence, filming an empty city lot into which Digital Domain composited a miniature building. Digital Domain’s model shop, under supervisor Alan Faucher, built the elevated, 25-foot-tall structure, rigging it with a series of cables and releases to effect a collapse cue.

A desert landscape is revealed below as the Talons, engaged in a test mission, emerge out of the clouds to out-maneuver a tracking missile, sometimes dropping just feet above the desert floor. Hynek shot the aerial photography in Australia from one of the Lear jets chartered for the production, which were typically equipped with a nose-mounted camera and one other mounted either at the top or the bottom of the fuselage. “The Lear was particularly useful for this opening sequence because it could fly very low and very fast,” Hynek said. “The pilot was very gung-ho about pushing that, and we sometimes flew as low as five feet above the ground, at 300 knots. We had to fly as if we were really dodging a missile, hugging the terrain, banking around mountains, and doing a whole series of stomach-churning rolls. I was at the back of the jet, looking at a monitor — and boy, that was a rough ride.” The sequence also featured EnGen desert terrain in six shots, one an all-CG shot over the back of a Talon as it performs a barrel roll.

To create the CG Talon model featured in the opening sequence and throughout the film, Digital Domain artists started with sketches from the production art department. “We also surveyed the full-scale planes,” noted Kelly Port, “took measurements of them and photographic reference to make sure our Talon was an exact match. That was critical, since there were going to be so many shots where we hooked up our CG Talon to the gimbal version.”

A technique dubbed ‘shampositing,’ a combination of shader work and compositing, enabled Digital Domain to avoid constant re-rendering as the CG Talon was integrated into CG or plate environments. The process involved rendering out layers of the image in RenderMan, with the key light pointed in a particular direction. “We would take all of those different layers and combine them in Nuke, our compositing software,” Port explained. “Then, if something wasn’t quite balanced, we could fix it in Nuke, rather than re-render it. Usually, adjustments are done within the shader itself. So you render something out, adjust the parameters, and then render it again — and you keep doing that until it looks right. This system allowed us to render it once, but split out all the different layers, so that we had control. Of course, if the light direction completely changed in a shot, we’d still have to go back and re-render it. But as long as we were dealing with the same basic lighting situation, we could use this approach. It was very successful.”



Visual effects director of photography Erik Nash shot the building implosion at Downey Studios, where all of the miniature photography for the show was accomplished. To accommodate the structure's disappearance below street level, the miniature crew mounted the model on a 30-foot-tall platform on an outdoor bluescreen stage. Cable releases created a sequential implosion event, toppling the rooftop section first, then a soft-plaster middlecore. Two outer building columns were reinforced with steel to withstand the force of the center column's collapse.

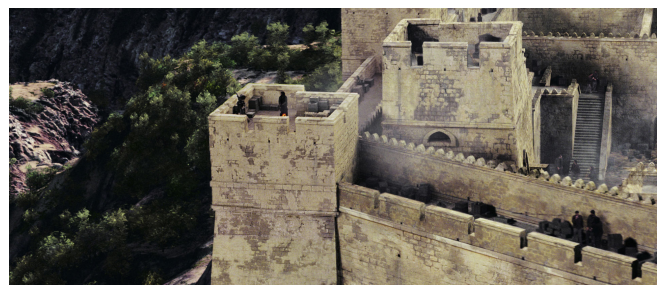
All shots of the planes were hand-animated by a team of Digital Domain animators, with flap movement the only procedural animation regularly used. “If the plane was banking,” explained Port, “the flaps would automatically move accordingly. But even there, we had overriding controls so we could change that if we wanted. The reason we had to hand-animate everything else was that Rob was very specific about each shot telling a specific story. Every shot in every sequence was very much directed.”

Having successfully completed their test mission, the three Talon pilots are assigned to an aircraft carrier, the USS Carl Vinson. Production shot main unit on a real aircraft carrier, the USS Abraham Lincoln, and even convinced the Navy to let them bring aboard their full-scale Talon and Eddie mockups. “The Navy has never allowed any foreign aircraft on a carrier,” Cohen said, “but they let us take these on, after we’d worked out all the safety concerns, such as what might happen in a hurricane. We broke them down in Australia and shipped them to San Diego, where the Lincoln was, and then reassembled them and got them onto the carrier by the time it was ready to pull out of harbor.”

Production ultimately conducted two second unit shoots on the aircraft carrier, in addition to the main unit shoot, capturing Spacecam shots of the ship from a helicopter, including shots of real F-18s landing on deck. In post, Digital Domain replaced the F-18s with CG Talons. “It was a wonderful lighting guide to have the F-18 there,” Joel Hynek noted. “We also tracked it and captured its motion, which gave us a lot of help in animating the landing Talons.”

Eddie is introduced shortly afterwards, coming in for a nighttime landing on the aircraft carrier. The initial reveal has the lethal-looking aircraft silhouetted against a CG moon, then sweeping behind a tower — the real aircraft carrier tower, tracked into the otherwise CG-animated shot — and landing on the deck. “Except for the little piece of tower,” said Hynek, “none of that was a plate. The surface that Eddie lands on was actually CG, with a photographic texture on it. The only plates we shot for this sequence were for scenes of Eddie going down the carrier elevator, which we shot day-for-night. There was an F-18 in the elevator originally, and we removed that and put our CG Eddie in its place.”

Together, the manned and unmanned stealth fighters engage in a training session intended to teach Eddie the unprogrammable, human aspects of flying missions. The training is interrupted by emergency orders sending the four aircraft on a real mission to Rangoon, where terrorist cells are convening on the rooftop of a downtown building. Shots of the planes flying over the Philippine Sea, en route to Rangoon, featured a CG ocean. “It’s so easy to do CG oceans now,” noted Hynek, “it was an easier solution than going out and trying to shoot ocean plates. And a CG ocean meant we could move the camera however we wanted.”



At Fort Jalil in Tajikistan, insurgents await the arrival of nuclear warheads, which they intend to launch into bordering Afghanistan. Near the Sydney airport, production built a partial front wall of the stone edifice as a practical set on which costumed extras could perform. Digital Domain extended the partial set digitally, then surrounded it with terrain created through EnGen, the company's proprietary digital environments tool. Using U.S. Geological Survey data, EnGen is able to re-create terrain from any spot on the globe, determining details

To minimize collateral damage, Ben executes a nosedive to gain velocity, then drops an implosion bomb directly onto the roof of the terrorist-seized building. Aerial plates for the sequence were filmed over Bangkok, Thailand. “As Ben’s plane nosedives,” noted Hynek, “we cut back and forth between Ben’s visor reflection of the city coming up and the POV of the ground getting closer and closer. From a helicopter, we shot tiles at all different heights, all the way up to about 8,000 feet. From that we made these large tile sets, which we could use as needed for the nosedive backgrounds.”

Upon its release, the bomb smashes through the roof and, subsequently, every floor of the building, finally landing at the ground floor. *Inside* a real building in Sydney, John Frazier set up a series of bulbs that flashed from the top story to the bottom, representing the bomb descending the interior of the structure. Additional live-action elements were captured on stage, where production created a greenscreen set for interior shots of the ceiling crashing down and punching through the top floor with the initial impact. The camera then flies into the hole that is made by the bomb’s entry, descending through the gutted floors of the building. At Downey Studios, director of visual effects photography Erik Nash shot a quarter-scale, forced-perspective hole set — built by Digital Domain model supervisor Alan Faucher and his crew — with greenscreen at the bottom so that the miniature element could be extended digitally.

With the detonation of the bomb, a fireball rises through the hole and then is ‘sucked’ back down as the implosion occurs. The in-camera effect was a pyro gag executed by Ian and Sherry O’Connor of O’Connor FX. “We knew that, as a backup, we could bring up the fireball and then just reverse the footage,” observed Ian O’Connor, “or use two elements and reverse one. But we wanted to at least try to get it in-camera.” The O’Connors mounted four large air movers on a box topped with tempered glass at the bottom of the multi-floor hole miniature. “Using a slow-burning material, we set off a fireball at the bottom of the miniature, which shot up between the floors. Then we broke the layer of glass on the vacuum chamber at the base, which sucked the fireball and smoke back down.” To add visual interest, air movers at the ceiling of the stage flew debris past camera. In post, Digital Domain enhanced the in-camera effect, adding CG smoke and debris.

For subsequent shots of the building collapsing, Digital Domain’s model shop built a miniature structure that was rigged to implode via a series of cables and releases. After first conducting tests with a four-story prototype model, modelmakers constructed the 1/12-scale, 25-foot-tall building from reference photographs of the Sydney structure. The miniature was built as three columns, with only the soft-plaster center column articulated to shatter during collapse. The two outer

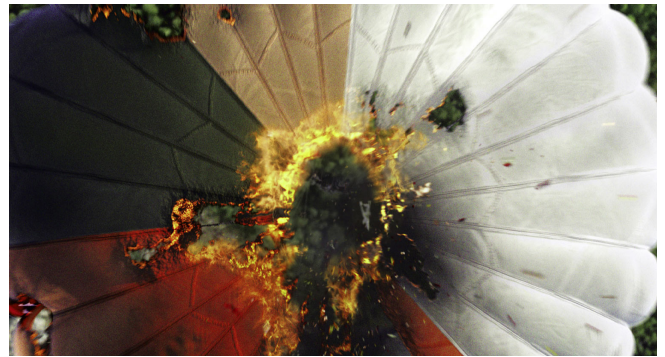
such as slope gradations, types and amounts of vegetation, snow lines and other features through an extensive set of procedural rules.



Ordered to shoot down the rogue drone aircraft – which has disobeyed orders and gone in search of unsanctioned targets – Henry pursues Eddie through mountainous canyons. Digital Domain used digital elevation map data from King’s Canyon in the Sierra Nevada mountains as the basis for the EnGen environment, vertically scaling up the data by a factor of one-and-a-half to narrow the canyon walls and make the chase sequence more harrowing. CG trees – currently beyond the scope of EnGen’s capabilities – were created in Houdini and composited into the landscape.

columns were made of steel skinned with wood, detailed with laser-cut acrylic. “That gave us two solid towers that could withstand the drop,” explained Faucher, “and not fall apart while the middle section was collapsing. To articulate a 25-foot-tall building in three sections — each of which weighed about a half ton — was very intricate and difficult.” The miniature was erected on a 30-foot-tall platform to facilitate the building’s disappearance below street level, and was surrounded by bluescreen. Five releases were required to topple the building — two to collapse the top section, and one release for each of the three columns. “There was a universal release, and then each subsequent release was staggered accordingly, down the line.”

The miniature photography was nested into an empty lot captured in one of the aerial plate shoots over Bangkok. “We shot that piece of empty ground and the surrounding buildings,” related Hynek, “starting at dusk and going into the night. That allowed us to combine dusk light with night light in our shots, so our blacks wouldn’t all be filled in.”



Visual effects supervisor Chris Godfrey and his Australia-based Animal Logic crew generated 29 shots for a sequence in which Kara ejects from her crippled Talon, then attempts to ‘outrun’ burning debris from the exploding aircraft by remaining in the ejection seat and delaying deployment of her parachute. Conceiving Kara’s freefall as a vertically-configured, classic movie car chase, Animal Logic created a sky environment that featured CG storm clouds, digital smoke trails and animated fiery debris. The company also wrote new proprietary software to simulate the billowing cloth of the parachute, which Kara finally deploys in the last few hundred feet of her descent.

Distant lightning captured in the Bangkok photography provided a real-world segue to the following sequence, in which Eddie and Ben are struck by lightning on their return from the *Rangoon* mission. “During one of our last nights of shooting in Thailand,” Hynek recalled, “there was a lightning storm going on. We were shooting at three frames per second; so, we didn’t know it, but we captured distant lightning flashes. In the footage, the sky was all lit up, and there were silhouetted clouds. So we used that to lead into this scene in which Eddie and the Talon are struck by lightning on their way back to the aircraft carrier.” Hand-drawn CG lightning augmented the distant lightning caught in Thailand. “There’s one shot where the lightning hits the Talon, and we’re flying along with it — so the lightning changes perspective as we go by, which is something we’d never done before. Again, it was a perspective shift to sell the sense of speed.” Animal Logic designed and contributed shots of lightning entering Eddie’s ‘digital nervous system.’ Shots of the compromised Eddie and Talon approaching the aircraft carrier featured a CG carrier, CG ocean and CG rain. Subsequent shots of their landing used a plate of the real carrier, but even those required the addition of CG rain where there was an absence of practical rainfall.

Departing for their next mission in the Pamir Mountains of Tajikistan, all four stealth planes take off simultaneously from the aircraft carrier in a ‘gaggle launch’ sequence. Shooting plates for the gaggle launch on the deck of the carrier required extraordinary cooperation from the Navy. “It was a big thing to ask of the carrier crew,” admitted Joel Hynek, “because it meant that they had to move all of their aircraft off the deck. But on our last day out with them, they said ‘Okay,’ and we got our shots.” In addition to clearing the deck, the aircraft carrier crew ran the catapults that pull the real jets during that last-day shoot, alleviating the need to generate the catapults digitally. Digital Domain painted out



To assume greater control over Kara’s fall, Cohen scrapped all but two shots from the live ‘helmet-cam’ footage that had been captured by stunt skydivers, and instead shot Jessica Biel on a greenscreen stage, harnessed to a two-axis rotator rig. Animal Logic composited those elements into its CG sky environment or – for the last 600 feet of her fall – into plate photography shot against a sandstone escarpment outside Sydney. Because Biel had been shot wearing a helmet without a visor – to avoid reflecting stage lights – final shots required the visual effects crew to track CG visors to the performer.



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superfluous people and equipment in the carrier background plates.

The mission in Tajikistan is to take out warlords who, from their stronghold in Fort Jalil, plan to launch Scud missiles equipped with nuclear warheads into neighboring Afghanistan. Production had built a set representing the front wall of Fort Jalil near the airport in Sydney, with extras as terrorists defending the enclave. Digital Domain then built and tracked CG extensions to the fort set, and composited EnGen terrain for wide shots. “We modeled the whole area around the fort based on reference photographs of a location in Pakistan,” said Kelly Port. “We re-created the quality of the earth, the colors, the nature of the vegetation — each one of those things became a mini-shader in EnGen. This was also one of the sequences where we had to do some hand-modeling on top of the procedural terrain generation, using shaders, displacement maps and texture maps.”

The signature shot of the Fort Jalil sequence starts with a satellite POV of the earth, descends toward Ta-jikistan, flies into the fort area — surrounded by all-EnGen terrain — then hooks up to a real helicopter move on a performer standing on a parapet of the live fort set. Another complex shot has the three Talons coming in low to take out the enemy anti-aircraft guns. “They shoot up the fort,” explained compositing supervisor Bryan Grill, “and then we track to Ben in his plane, following it as he turns, then zooming in and hooking up to a gimbal shot — which is the only real thing in the shot. What makes this shot remarkable in terms of compositing is just the dynamics and composition of it. It feels as if you’re one of the planes, right in the middle of the action. And the scope of it is something you couldn’t really do practically.”

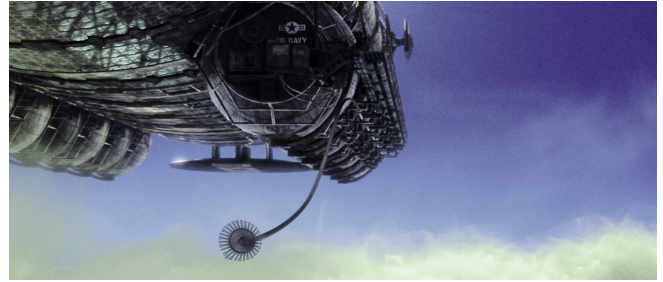
After the Fort Jalil attack — during which the now self-aware Eddie disobeys orders — the UCAV leaves the formation, in search of ‘other targets.’ On orders to bring down the rogue warplane, Henry pursues Eddie in a dynamic chase through a narrow canyon — a mostly CG environment based on aerial footage of King’s Canyon in the Sierra Nevadas. “At first we were going to try to do this sequence mostly with plates,” said Hynek, “but Rob wanted some pretty extreme animation, with the planes going right down into the canyon, flying in and out of it, the walls of the canyon getting tighter and tighter. That wasn’t something we could really do with aerial plates. So Brad Herman’s team made an EnGen model based on the digital elevation map of King’s Canyon, and scaled it up vertically by a factor of one-and-a-half, which made the canyon walls very narrow.”

Henry fires a tracking missile, which Eddie dodges through some fast and furious weaving maneuvers. A last-second bank sends the missile exploding into a cliff-face. His vision obscured by the explosion, Henry slams into the ridge, his plane erupting into flames. Both a miniature Talon and a miniature cliff-face were built to realize the sequence. Designed as a 360-frame shot, the destruction of Henry’s plane was executed as a sequential event, rather than one big explosion. “It couldn’t just start breaking apart and shear towards the back,” explained Alan Faucher. “It had to look as if it was a huge mass driving into the mountain. So we built the nose out of lead, which would buckle upon impact, and then set off a sequenced explosion.”

To avoid scale-shattering bouncing as the Talon model hit the rock-solid ridge miniature — made of white bead foam and sprayed with a thick layer of polyester coating to strengthen it — the model crew heavily prescored the lead nose. “The lead was cut in so many places,” observed Faucher, “the nose basically had no structure — and yet it had to hold its shape until impact. It was a delicate balance.” Mechanical engineer Scott Salsa rigged a pole that ran through the cliff miniature and into the center of the plane. Releasing 1,000 pounds of counterweights pulled the rod and rammed the plane into the face of the cliff model, buckling the soft lead nose. At a predesignated point, a series of charges ignited, blowing up the Talon model. Erik Nash photographed the miniature gag at 300 frames per second, while O’Connor FX orchestrated the pyrotechnics.

Saddened and angered by the death of Henry, Kara and Ben separate to ramp up their search for Eddie. In the skies over North Korea, Kara is forced to eject when her Talon, damaged by debris from Henry’s crash, begins to seriously malfunction. For shots of the Talon exploding in midair, the model shop built a lightweight model out of resin, which was suspended on cables between two lifts, filled with pyro, and shot on the Downey Studios backlot. “There were some simple manual pullers to create some motion in the plane as it hung there,” said Ian O’Connor, “making it rock back and forth. The cameras were down on the ground, and we were up in a lift, firing a four-step explosion in the plane.”

Kara attempts to ‘outrun’ the falling, burning debris by remaining in the heavy ejection seat and deploying her chute at the last possible moment. Digital Domain created shots leading up to the ejection, with Jessica Biel in the rotating cockpit gimbal, while Animal Logic contributed 29 shots for her actual freefall. The challenge was primarily an aesthetic one — how to make shots of a person falling through the air look interesting. “Somebody freefalling in the middle of empty space doesn’t look like anything,” noted Animal Logic visual effects supervisor Chris Godfrey. “We looked at some footage from a camera that had been thrown out of a plane, and the first four seconds were really interesting. The last two seconds, just before it hit the ground, were also interesting — but everything in between was hugely dreary! So we decided to put in a CG storm cloud that she could fly past, to create a sense of movement in the shots.”



Ben attempts to intercept Eddie at a robotic refueling station hovering at 60,000 feet. Dubbed ‘Camel Hump 9,’ the dirigible was imagined by Rob Cohen prior to his learning that the military is currently developing similar high-altitude refueling stations. Digital Domain built the detailed Camel Hump computer model, and also generated vaporized fuel spewing from a ruptured hose, forming a ring as the dirigible circles the sky. Artists spent months devising a suitable look for the fuel ring, finally producing a tinted gaseous cloud that was distinguishable from exhaust or vapor trails.



As Eddie flies through the fuel ring, heat from the plane’s engines causes the fuel to ignite. Digital Domain elevated its fire simulation techniques to produce the most advanced, realistic flame effects in the company’s history. Tools written to create avalanche dynamics for Rob Cohen’s previous XXX were refined and applied to the CG inferno, creating predetermined fire ‘events,’ such as explosions and tendrils of flame licking the sky. The CG fire was augmented with practical fire elements shot at Digital Domain by O’Connor FX.

Animal Logic also created visual interest by introducing an element of unpredictability, a characteristic that was evident in skydiver helmet-cam footage that had been shot for the sequence — one stunt diver shooting another in an ejection seat. “The unpredictability of that live-action footage was fabulous,” God-frey recalled. “One of the skydivers would hit an air pocket and suddenly move 30 or 40 feet away. Things would move really quickly, and then slow down and float for a while, then fly off again. Because of the aerodynamics of the diver in the ejection chair, it was very uncontrolled.” As interesting as the random live-action footage was, it did not allow for the level of directorial control Cohen desired. All but two shots of the stunt-diver footage were scrapped, and the sequence was instead realized by inserting greenscreen footage of Jessica Biel on a rotator rig into a CG sky environment. “Once we decided that we were going to take it into the stage, where we would have a lot more control over it, we agreed that it would be most dramatic if we staged it like a car chase out of a movie. So the coverage was very similar to that. Kara basically travels in a line, and the ‘enemy’ — in this case, the debris — is flying around her and trying to cut across her.”

The greenscreen material was shot in Australia, with Biel or her stunt double seated in a two-axis rotator rig capable of spinning both laterally and head-over-tail. Animal Logic composited the live material into digital backgrounds that included 3D clouds, digital smoke trails and burning debris — all created via proprietary software. “One of the things I wanted to do to enhance the drama,” said Godfrey, “was to make the movement of the raining debris random and chaotic, so that at any point any one of these objects could slice across her path and burn her or cut her. Chris Cooper wrote a procedural animation, so that when we dropped any of these objects, they would cut or slice or rotate, depending on the shape. That added a nice level of variation. We ended up exploding 600 pieces of debris, 100 of which were burning. About 80 percent of that was procedural. The rest — the hero pieces that came near her — I choreographed with an animator and Rob. All of this debris, clouds, mist and haze became a tangible environment that she could fall through to give us a sense of speed.” Animal Logic also wrote proprietary software to simulate the billowing parachute. To create the ground rushing up to meet her in the last 600 feet of Kara’s fall, Animal Logic shot background plates against a sandstone escarpment near Sydney.

Ben has his own problems in the skies nearing Russia, where he attempts to intercept Eddie as he refuels at a robotic dirigible refueling station, called 'Camel Hump 9,' hovering at 60,000 feet. Cohen had conceived the fictional high-altitude refueling dirigible before learning that the military has plans in place to build such structures. Other than cockpit shots of Josh Lucas, everything in the Camel Hump sequence was computer generated, including the refueling station itself. "That was a very complex CG model," said Kelly Port. "It had a lot of intricate detail in its internal structure, and a translucent skin on the outside that revealed that detailed interior. Just rendering that thing was a beast."



Having ventured into Russian airspace, Eddie and Ben engage in a dogfight with four Russian SU-37 Terminator jets. The entire battle was computer generated, with animated jets maneuvering within all-digital skies. For every aerial sequence in the film, Digital Domain filled empty virtual skies with clouds, missile streams, heat distortion, wingtip vortices and other elements to create physical interaction with the aircraft and heighten the sense of speed.

As Ben refuels from a Camel Hump hose, a fuel line ruptured by Eddie surrounds him in a ring of flammable gas. "Getting that cloud of fuel to look right was extremely difficult," recalled Joel Hynek. "Rob wanted to make sure it wouldn't just look like exhaust or a vapor trail. It's kind of like a cloud, and yet it had to have structure — but not too much structure, otherwise it wouldn't look like vaporous, atomized fuel. It was tricky." The cloud of fuel ignites with the heat from Eddie's engine on a fly-through, erupting into a ring of fire in the sky. "That was the most advanced CG fire we've ever done. Markus Kurtz, our CG supervisor, did a marvelous job of creating a system that would make it look like an explosion. It was similar to what we did for the avalanche in XXX, where we laid 'ground mines' for places where the snow would explode in tendrils. Here, we had a leading wave of fire, and when it got to specific places, it would create explosions. Those were all prearranged as procedural events."

Having entered Russian airspace, Ben and Eddie are engaged in a dogfight with four Russian SU-37 fighters. Rather than a linear dogfight, Cohen envisioned a three-dimensional aerial battle, choreographed to play out on multiple planes. To realize that concept, Digital Domain created a pan-and-tilt sky environment that could accommodate any camera angle or movement of the CG planes. "We also created what we called the 'playground,'" said Hynek, "which was a bunch of very high-rez clouds — and Rob could do anything he wanted in there. This dogfight was the first sequence we prevized, and it really opened the door to the kinds of flying action we would be doing. It ended up being the last sequence we animated, which was good because, by then, the animators really had a great feel for the flying stuff."

More than any other aerial sequence in the film, the dogfight evolved from the original previz animation in postproduction, with established shots changing radically and entirely new shots being added. Some of those altered shots featured gimbal cockpit footage that had been filmed according to the original animatics, requiring some after-the-fact finessing of the greenscreen material. "We had to do some re-animation on the gimbal stuff," said Port, "not only for the dogfight sequence, but for others. As cool as the gimbal was, sometimes — once we tracked what it had done — we could see that the movement wasn't really appropriate. If the gimbal pitched just a little bit,

for example, by the time we tracked our 69-foot-long CG plane to it, it looked like a bucking bronco. So we had to tone down the movements sometimes, effectively re-animating something that had already been shot, which was very tricky. We'd track what the camera was doing and what the gimbal was doing; then we'd animate what we wanted the camera to be doing. We'd project the original image, using this new animated camera, so now you'd see that original image through the lens of the corrected camera. We were reprojecting the original image onto new animation, basically using what was originally shot as a texture map. You'd think there wouldn't be much room for adjusting something like that; but we found we could separate out the pilot in the gimbal and reproject that onto the new animation, and it would still look believable, even if we were a full 90 degrees off from the original image." Technical integration lead Swen Gillberg oversaw reprojection tasks.



Shots of fiery SU-37 destruction were achieved with jet models built from kits and customized by the Digital Domain model shop, then rigged with pyrotechnics by O'Connor FX and filmed by Erik Nash in a variety of configurations on the Downey stage. Ian O'Connor plots placement of pyrotechnic charges on one of the SU-37s, while Digital Domain modelmaker Mike Schoener touches up the breakaway tail section.

In some cases, a shot had changed so radically, it was easier to render and animate an all-CG pilot and cockpit than to try to retro-fit a gimbal cockpit element. “CG supervisor Vernon Wilbert and his team built all the main characters as fully-rigged digital models,” said Port, “all the way down to the toes. And we had a full CG interior for each of the planes. We used the CG cockpit and pilots for distant shots, as well, and kept the gimbal stuff for closer shots.”

Though the flying SU-37s were always CG, shots of the aircraft being destroyed by Eddie and Talon gunfire were achieved with practical models. To build the models, Faucher and his team started with a 1/6-scale SU-37 model kit made by a company in France. “We bought ten of these kits,” said Faucher, “did a custom camouflage paint job on them, and built new, more realistic bulkheads and support systems to use with their shells — so every time one of the planes got hit, you’d see it split apart, revealing these very realistic internal guts. We built eight of these models — one plus a backup for each of the four planes.”

Erik Nash shot the SU-37 model explosions, translating the dynamic camera style in the previz to the practical setups. “In one shot,” said Ian O’Connor, “an SU-37 comes into frame, already being hit by gunfire. Then, as it flies toward us, its wing is chewed off, it separates, and the camera actually flies in between the wing and the plane. The plane goes camera right and the wing goes camera left.” After much discussion as to how to achieve the shot in-camera, Sherry O’Connor suggested hanging the model upside down from a lift. O’Connor FX triggered bullet hits and a series of fiery pyro charges, and quickly followed that with the separation of the wing from the plane, achieved with a wing-yank mechanism. “As the plane came in, we blew the wing directly out to the side. Then, just milliseconds after that, a cable yanked back the fuselage. All of this happened as the gaffer pushed a dolly through the middle.” For shots of yet another plane being destroyed, O’Connor FX executed a huge explosion in the rear of an SU-37 model to simulate a missile hit, then followed it with a chased-sequence explosion that blew through the length of the plane.

Their aircraft compromised, Ben and Eddie make an emergency landing at a clandestine corporate air base in Alaska. The approach to Alaska featured aerial plates shot over Mount Cook in New Zealand, with EnGen filling in for shots not covered in the aerial photography. For the actual landing at the base, Alan Faucher’s model crew built a 1/8-scale Talon model measuring six feet long, with a wingspan of seven feet, and heavily reinforced to withstand multiple crash-landings. Scott Salsa devised a conveyor belt for the initial runway impact and shots of the landing gear breaking off. The



For one SU-37 explosion, the miniature photography crew dollied the camera toward the model – hung from a crane – as O’Connor FX fired pyrotechnics and separated the wing from the fuselage via a mechanical rig. Two remotely-operated cameras – one on a Condor crane above the model and one above the greenscreen – captured additional angles.

runway was later replaced with a CG surface. For subsequent shots of the plane careening down the runway, the model crew winch-pulled the model down a 100-foot-long deck that was dressed to match the first-unit landing strip. Digital Domain composited the miniature footage into a surrounding landscape.

Digital artists enhanced the in-camera shots with CG sparks, smoke, fire and canopies, while compositors tracked in greenscreen cockpit elements. Closeups of Ben as he executes the bumpy landing featured some of the most violent gimbal footage in the show. “Rob really put Josh Lucas through the mill for this scene,” recalled Joel Hynek, “trying to get some real, physical interaction. The camera flies into the cockpit as he smashes down onto the runway, and we see Ben hit his head on the front panel. Josh really did smash his head on the panel while riding the bucking gimbal. I think he even got a mild concussion from it.”

Covert operatives on the base try to kill Ben, who escapes by boarding Eddie and crashing through a hangar door. Live-action for the scene was shot at an airport in Scofield, Australia. The art department built a special hangar door, which John Frazier blew up to simulate Eddie’s crashing through. Frazier also rigged full-scale vehicles to flip over in the blast, some landing on top of strategically placed cameras. The CG Eddie was then composited into the airport footage.

Ben pilots Eddie to the demilitarized zone between North and South Korea, intent on rescuing Kara. There, as Ben and Kara are about to be fired upon by a MIL-8 helicopter gunship, Eddie saves them — and sacrifices himself — by deliberately crashing into the aircraft. Production had shot a real helicopter for the lead-up to the crash, as well as some independent full-scale explosions for the aftermath, but the actual impact was achieved using helicopter and Eddie miniatures. “We moved the Eddie model on a track toward the helicopter model, which was suspended from above with an arm to allow for impact reaction,” said Alan Faucher. “Then there was the impact and the explosion.”

The explosion was one of the biggest orchestrated by O’Connor FX for the show. “This finale was like John Woo on steroids,” Ian O’Connor said. “In order to match the huge full-scale explosions production had shot, we had to come up with a new chemical mix that we could load into the bottom of both the model plane and the model helicopter, so as they initially went off we could get all of this flame raining down under them. We also had to get a physical move. The helicopter was on a spring-loaded mount as it exploded, and the Eddie model, which was on a dolly, was pushed into it. We physically triggered our sequencer for that explosion on the dolly track.” Digital Domain added CG rotors to the miniature helicopter, and composited the miniature pyro explosion into a location background plate.

Stealth represented a raising of the bar for movies showcasing top-gun pilots and their amazing flying machines. As the film neared release, Rob Cohen credited Digital Domain with providing solutions that made his only-dreamt-of shots a reality. And Digital Domain credited Cohen with creating a collaborative atmosphere in which the director was on a first-name basis with every digital artist, and in which creativity was rewarded with appreciation. The experience, the third time Cohen and Digital Domain have united to make a movie, just served to more tightly bind this particular director to this particular group of visual effects artists.

“We had the effects reel going at the wrap party,” Cohen recalled, “and I said to all the people from Digital Domain — all 300 of them — that making *Stealth* was the most intimate experience I’d had with a large group of people since my party days in the Seventies! It was a goofy thing to say, but I meant it. Each shot on that reel had its own story, with its own unique set of challenges and crises. But it was all there — 60,000 frames, all hand-done by the most brilliant animators, compositors and lighters. It’s an unbelievable achievement. *If I never made another movie, I think I could rest on this one and be proud.*”

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Alien Apocalypse

image

ARTICLE BY JOE FORDHAM

Industrial Light & Magic senior visual effects supervisor Dennis Muren was seven years old when he first saw George Pal's 1953 adaptation of H.G. Wells' Martian invasion tale, *The War of the Worlds*. "It knocked me out as a kid," said Muren, "and it had always been a fantasy project for me. Then Steven Spielberg called me about *War of the Worlds* in June 2004 — I had no idea he'd been planning it — and suddenly it happened, right out of nowhere."

Tom Cruise and his producing partner, Paula Wagner, had been developing the project since 1998; but the Paramount and DreamWorks co-production was not initiated until a shift in Cruise's and Spielberg's schedules created a narrow window of opportunity. The screenplay by Josh Friedman and David Koepp updated the Victorian English setting of Wells' novel to present day, middle-class America and told the story of the alien invasion through the eyes of New Jersey dockworker Ray Ferrier (Cruise) — divorced father of seven-year-old Rachel (Dakota Fanning) and teenage son Robbie (Justin Chatwin) — who struggles to survive as his world is torn apart by extraterrestrial warfare.

Spielberg turned to his longtime collaborators at ILM to determine if the project was logistically feasible on the scale that he imagined and in the amount of time available. "We were supposed to start shooting November 5," Muren recalled, "and have it in theaters by June. Steven wanted to know if we could make that deadline, but still keep the quality and the number of effects he wanted. At that time, I hadn't read the script, so I didn't know exactly what he had in mind; but it didn't really matter, because this was Steven, and I was ready to do it."

Spielberg's plan was to adopt a gritty, contemporary filming style with director of photography Janusz Kaminski and production designer Rick Carter, shooting practical locations and using visual effects to incorporate alien tripod machines and their destructive impact. Physical effects supervisor Daniel Sudick supplied practical and mechanical effects while Stan Winston Studio, Steve Johnson's Edge FX and Harlow FX handled prosthetic effects, under makeup department head Lois Burwell.

To explore effects strategies, the production enlisted the services of previsualization supervisor Dan Gregoire, who had previously worked as part of Lucasfilm's JAK Film rebel unit, conceptualizing action sequences for *Revenge of the Sith*. Working as an independent contractor through his own Halon Entertainment, Gregoire and his associates developed animatics, working alongside storyboard artist David Lowery at Spielberg's New Hampshire home. Gregoire then worked at the director's side through the first unit shoot. "I visited sets, went on location scouts and photographed the heck out of everything," Gregoire observed. "We built general shapes of buildings in 3D and used photographs, my own measurements and aerial photography to lay out scenes. Steven used those models to familiarize himself with the environments. When he found an angle he liked, we made a note or set a keyframe, he made stick-figure sketches of compositions, and we integrated those into the digital environment."

Previz became a vital and malleable tool, allowing the director to communicate specifics of camera blocking while remaining light on his feet. “I thought Steven might do what he’d done in the past,” Muren noted, “tossing storyboards aside when he got on the set. My concern here was, ‘Is Steven going to stick to the animatics?’ I didn’t expect him to. I thought he’d shoot from the hip. But he did stick to the previz, most of the time, and that allowed us to concentrate on the work. And, of course, whenever Steven came up with a new idea, Dan could update the previz.”

With plans progressing, Muren brought in visual effects supervisor Pablo Helman to share the workload, joined on set by ILM producer Sandra Scott. Back at ILM, CG supervisor Michael Di Como led the ‘Muren unit,’ concentrating on tripod scenes and an action sequence featuring an attack on a ferry boat. Digital production manager Curt Miyashiro led the ‘Pablo unit,’ focusing on a large-scale combat sequence and an extended scene involving a tentacle-like tripod probe and the appearance of the aliens.

In addition to their supervisory duties, Miyashiro and Di Como oversaw implementation of a new technical initiative that ILM had been refining over a number of years, utilized to full effect on the rapid-paced production. “I’d been working on upgrading our toolset and standards of practice as a way of enabling our artists to do more than one job,” stated Muren. “To do that, the tools had to be easier to use and we had to consolidate things. This went against the notion of an ‘expert’ user, and encouraged people to be ‘generalists.’ Plenty of artists today can create good work using almost any tool, and we wanted to give our artists an opportunity to do that. *Instead* of having the tool run the show, we’d have the artist run the show.”

That new toolset, Zeno, had been used to great effect on *Revenge of the Sith*, particularly the digital environment package, Zenviro. *War of the Worlds* relied more heavily on Zeno’s digital lighting tool, Lux. Miyashiro oversaw implementation of the Zeno pipeline and worked with Di Como to unify its different modes of operation, allowing a team of 45 technical directors to handle matchmoves, animation, simulations, digital matte paintings and lighting in a single platform. “If we had a tripod creature looking really great,” explained Di Como, “but we needed to make one little alteration in one shot, like add a piece of battle damage, instead of sending it all the way back to Viewpaint, a TD could use the digimatte and painting tools in Zeno and Lux, grab a texture from a weapons photo and create a shot-specific paintwork. It was a steep learning curve, requiring a lot of technical ‘band-aids,’ because we also had to get shots out the door; but the TDs really proved themselves under circumstances where the ground was moving below their feet.”



Like the classic 1950s-era screen adaptation of H.G. Wells' alien invasion novel, *War of the*

Worlds updated the Victorian English setting to contemporary America, this time telling the story through the eyes of New Jersey dockworker Ray Ferrier (Tom Cruise). Director Steven Spielberg realized the film on a breakneck shooting and postproduction schedule by calling on a pool of long-time collaborators, including Industrial Light & Magic senior visual effects supervisor Dennis Muren. Among its other tasks, the team at ILM brought to life an extraterrestrial army of walking tripod war machines, seen from an intimate human perspective, transferring alien-manned capsules into subterranean locations.

The film opens with narration from Wells' book, accompanied by images of microbial life generated by Picture Mill, foreshadowing the extraterrestrial threat without specifying its origin. "The aliens aren't necessarily from Mars," observed Muren. "We've been to Mars now and found nothing; so Steven decided that we wouldn't know where they came from." ILM also updated the aliens' mode of transport from the giant metallic cylinders described in Wells' book to ferocious electromagnetic discharges.

Ray Ferrier first witnesses the atmospheric phenomena in the form of bizarre cloud formations above his New Jersey home. ILM shot plates with principals on location in Bayonne, New Jersey, and then generated effects that were a deliberate stylistic departure from cloud-tank images seen in Spielberg's earlier productions and the films they had influenced. "The last time I shot a cloud-tank effect was for the alien ship coming out of the clouds for *Independence Day*," remarked Pablo Helman. "We didn't want to go that route. Cloud-tank effects look very pretty, but they are difficult to key and difficult to manipulate once you establish the performance." Digimatte artist Brian Flora instead shot illuminated fiberfill cotton clouds. "Steven didn't want the lightning to dissolve from one layer to another. He wanted solid geometry with lightning inside. So we photographed cotton clouds backlit, frontlit and underlit, then took that into our *Inferno* system and worked all the layers, warping them organically."



The threatening nature of the alien visitation is revealed when a crowd of onlookers converges on an intersection where a sinkhole has opened at a spot struck by multiple lightning bolts. Spielberg previsualized the sequence with 3D animatics created by Halon Entertainment, and then filmed live-action on location, making strategic but limited use of physical effects for shots of the intersections suddenly erupting. ILM generated the remainder of the sequence, shearing off the front of a church and creating fissures in the street surface through rigid dynamics simulations, procedural animation and miniature elements blended into live-action plates.



Using architectural drawings, photographs and measurements gathered from the location, the ILM model shop constructed a miniature church and several adjoining

The true nature of the alien discharge is revealed when an electrical impact draws Ray and a crowd of onlookers to a downtown intersection where a sinkhole has opened up in the center of the street.

The sequence, the first photographed for the film, became a proving ground for ILM's visual effects methodology. "I took an approach on this film that I'd been thinking about for a while," said Muren, "which was to manipulate real images, inserting CG or miniature elements only where we really needed them."

Closely attending previsualizations, Spielberg shot long-running, documentary-style intersection plates on location in Bayonne, without the use of motion control and with few practical effects gags. ILM created fissures emanating from the sinkhole using technology developed for ripping apart giant spaceships in *Revenge of the Sith*. "Sequence supervisor Erik Krumery used some procedural rules in Maya to make the ground tilt and crack, applying fields of influence," explained Michael Di Como. "For the first shots in the sequence, where we were really scrutinizing the cracks, we used rigid dynamic simulations inside Zeno to add realism."

Shots of cracks running up the side of a church and severing its façade were achieved with miniatures built from on-set reference. "Dennis and our lead location data capture artist Duncan Blackman gathered a lot of information for us," said miniature supervisor Steve Gawley. "Senior modelmaker Bryan Dewe and his crew used that information and Rick Carter's architectural drawings to build a photoreal 1/16-scale model of the church and its surrounding buildings. We programmed that information into our model shop computers; then our computer-guided laser cutter translated that data into precise laser-cut surface detail. Duncan's photo reference from set enabled us to construct several stages of destruction on the church. Modelmaker John Duncan helped to establish the look of the shear damage, and painter Melanie Walas created a photoreal paint finish."

Lead digital matte artist Joshua Ong took high-resolution digital images of the miniature church and assembled CG textures. Lead CG layout artist Terry Chostner's matchmove team then built proxy geometry, mapped on textures and animated the fracturing effect. "When the church shears," observed Muren, "the only miniature in the shot is the little area that splits, with bricks falling down. The front and back of the church were real. We split the building with projection mapping, then inserted bricks coming apart with paintwork here and there. There's no clue that it's going to be an effects shot until the effect begins, because it's all natural."

Another practical miniature was the foundation for an effect of the street swelling in an enormous bubble of earth and asphalt. "We shot the intersection sinkhole outside on the slab at ILM using real sunlight," said Gawley. "Senior modelmaker Lorne Peterson, our resident organic specialist, and his crew developed a special recipe that looked like 1/16-scale dirt and miniature asphalt. We pre-cracked the street surface; then practical effects supervisors Geoff Heron and Robbie Clot and their crew constructed a mechanical rig to make the two-ton, nine-foot-diameter crater of dirt rise slowly then drop very rapidly, creating a large and deep sinkhole." Visual effects director of photography Kim Marks shot the element at 96 frames per second. Compositors warped it and blended it to the

buildings. Computer-guided laser cutters translated location data into precise surface detail, allowing Kim Marks also shot a miniature element of the street swelling and erupting. ILM compositors warped the stages of destruction. Modelmaker Pierre Mäurer segs to element and blended it into the live-action plate, with final detailing prior to the shoot on the ILM backlot slab. additional debris issuing from cracks.

plate with additional debris issuing from cracks and streams of dirt spilling off an alien war machine that emerges from the earth, awakened from subterranean slumber.

The tripods, seen in 123 shots, were a design priority in preproduction, requiring the pooled resources of Rick Carter's art department, conceptual designer Doug Chiang's Ice Blink Studios, ILM art director Christian Alzmann and his team, as well as familiarity with previous adaptations of Wells' story. "I first thought that the tripods might not walk," Muren commented. "That was what they had done in the 1953 movie — they didn't know how to walk them so they went with an anti-gravity device, flying them by wires. But Steven kept coming back to the idea of a walking machine. I was worried that tripods would look too much like Victorian technology, rather than something contemporary audiences would go for. We kept in mind that the tripods couldn't look too clumsy or labored as they moved around — but they also had to look more organic than computer graphics."

As the basis for the tripod, Spielberg selected designs that depicted an anvil-shaped head, graceful flowing legs and whip-like mechanical tentacles. Simultaneous to the design work, previsualization artists referenced conceptual art to build an articulated 3D model in Maya that would help to plan blocking of the giant machines in shooting locations. "It was a fully-functional rig with 24 tentacles, extendable legs, moving toes, and a pivoting and extending head," related Dan Gregoire. "That gave us the correct scale of the tripod in the town, with realistic cameras in the digital environment. When Steven set up a shot, they matched to that. There was no motion control, it was all freeform, but they always had a solid starting point, midpoint and end point."

ILM's hard surface modeling team, led by Russell Paul, completed the tripod model, and creature supervisor Tim McLaughlin's team developed animation rigging. Animation supervisor Randal Dutra then led a team of 19 animators — including associate animation supervisors Jenn Emberly and Tim Harrington — who gave life to the war machine, creating a performance that evoked both creature and mechanical characteristics. "Certain shots exploited the mechanical aspects of the tripods," said Dutra, "other shots exploited the organic. That kept the work fresh and unpredictable. The other thing that made it interesting is that most CG animators are used to working in mass, moving joints and solid objects. The tripod legs required a completely different aesthetic, working in pure line, favoring reverse S-curves and staying away from the letter 'C' to maintain this graceful movement." Animators took inspiration for tripod poses from aquatic creatures. "The tripods had what I called 'terrestrial buoyancy.' The long thin legs moved in a very hypnotic way, almost like jellyfish, but they also had to be believable in earth's gravity. It was really tricky to keep a sense of weight and yet still keep this fluidity."



The tripod's head has a series of three large, jointed legs that are made of a dark, metallic material. The legs are designed to look like they are made of a single piece of metal, with no visible joints or seams. The tripod is shown in a dark, industrial setting, with a large, curved structure in the background. The lighting is dramatic, with strong highlights and deep shadows, emphasizing the metallic texture of the tripod.

The tripod color schemes were based initially on a bronze-colored 15-inch maquette built by ILM concept modeler John Goodson. “The look changed as we started getting plates back from set,” commented sequence supervisor Robert Marinic. “Dennis wanted it to look more like an alien alloy. We built custom shaders with iridescence and color variation to produce a more brushed-steel look.” Viewpaint artists hand-painted texture maps to create dirt and grime, while TDs introduced subtle lighting effects around the lower edge of the tripod head to emphasize the creature’s organic nature. “We created what we called a ‘stained-glass’ look, a dense translucency that suggested a hint of changing colors from an internal light source. We created that by tracking points from the 3D geometry and running noise through those points to create an undulating effect.”

Tripod renders broke down into multiple passes, allowing compositing sequence supervisor Jay Cooper and his team to blend textures into the location, with first glimpses of the machine partially obscured by a foreground tree and gushing water from a ruptured fire hydrant, backlit against a hazy, burnt-out sky. “Everything was so clean and pretty in the renders,” said compositing supervisor Marshall Krasser, “we really had to mess things up to work the tripod into the environment, adding atmosphere and practical debris. We took our keys from plates and re-created photographic effects by analyzing background luminance and how light flared and wrapped over foreground objects.”



Ray Ferrier loads his children into a minivan and tries to outrun a section of bridge that shatters when struck by the alien heat-ray blasts. Visual effects supervisor Pablo Helman oversaw the shot, which began with a location plate trucking back with the van. ILM artists motion-tracked the plate, removed the bridge superstructure and supports, and generated the collapsing bridge sections using rigid body dynamics. Compositor then layered in approximately 400 elements, including miniature pyrotechnics, airborne 3D cars, a contorting tanker truck and layers of dust and debris.



The Zeno pipeline allowed for iterations of the creature's blazing cyclops eye. "Renders for the tripod lights weren't giving us the volumetric illumination we wanted," observed Krasser. "We ended up using an image of my Toyota 4Runner headlamp as the core illumination. We took a 2D practical-smoke noise pattern, moved that through the light to create a gaseous pulsation, broke that up with dither, displacement and ripple, broke that up with an additional noise pass at a different frequency, and in some shots added debris or rain falling down in front. It gave the light a very ethereal, organic feel, like it was 'breathing,' and we cranked up the intensity in the comp to make it look really hot. We did that for the headlights, sidelights and what I called little 'dashlights' around the edge."

The tripod rises 140 feet above the intersection, voids itself by ejecting earth and steam from its portals, then emits an ululating battle cry and unleashes a searing heat ray that turns human flesh to dust. "It took a lot of time to come up with the heat ray," commented Dennis Muren. "We didn't want it to look like a science fiction movie effect. When we were far enough into the show to see that Steven was going toward a more organic tripod, it seemed like the heat ray should be less like something out of *Star Wars* and nowhere near as 'sparky' as in the original movie." ILM experimented with heat rays as electrical pulses and glowing plasma balls before *Inferno* artist Sebastien Moreau arrived at the final concept in the last six weeks of postproduction. "We generated CG particles that followed real perspective, then manipulated, blurred and layered them with a color change — the color was Steven's idea. It had the property of real physics, but with a subtle sci-fi feel."

The heat-ray impacts instantly drain all moisture from victims, causing them to disintegrate inside their clothes. The physical effects team experimented with shooting elements of exploding bodies using pyrotechnic effects. Real clothing and exploding powder were also shot at high speeds against bluescreen as composite elements. Spielberg filmed heat-ray victims fleeing the tripod, reacting in agony and simply falling to the ground. ILM's paint and roto department, led by Amy Shepard, then eliminated the actors from frame. "These shots were a real testament to Amy's team," said Michael Di Como. "In one shot, the camera was pulling back, and there were people falling everywhere. One guy fell with a dozen

Ray Ferrier loads his children into a minivan and tries to outrun a section of bridge that shatters when struck by the alien heat-ray blasts. Visual effects supervisor Pablo Helman oversaw the shot, which began with a location plate trucking back with the van. ILM artists motion-tracked the plate, removed the bridge superstructure and supports, and generated the collapsing bridge sections using rigid body dynamics. Compositors then layered in approximately 400 elements, including miniature pyrotechnics, airborne 3D cars, a contorting tanker truck and layers of dust and debris.



Ray Ferrier loads his children into a minivan and tries to outrun a section of bridge that shatters when struck by the alien heat-ray blasts. Visual effects supervisor Pablo Helman oversaw the shot, which began with a location plate trucking back with the van. ILM artists motion-tracked the plate, removed the bridge superstructure and supports, and generated the collapsing bridge sections using rigid body dynamics. Compositors then layered in approximately 400 elements, including miniature pyrotechnics, airborne 3D cars, a contorting tanker truck and layers of dust and debris.

people in front of him and dozens behind — every one of which we had to add back to erase him from the frame. We did that by offsetting and compositing people, using procedural replication of ground and hand painting.” Spielberg’s brief for sudden vaporizations into thick clouds of dust allowed paint artists to bring plates to 80-percent perfection before adding crumbling bodies. Victims’ clothes were then animated with digital cloth simulations to fall and float, filling the street like so many lost souls.

Ferrier flees town with his children by stealing a minivan from a neighborhood garage, which is suddenly destroyed as he pulls away. ILM obliterated the garage owner (Lenny Venito) with a heat-ray effect, then blended an exploding miniature of the garage with a full-scale pyrotechnic effect rigged on location by the physical effects team.

The neighborhood escape took on more complexity the morning of the shoot. “The way the scene played in the script,” recalled Pablo Helman, “Ray stole this vehicle, the gas station blew up — and that was it. We were setting up the shot at the gas station at about 6:30 in the morning, and Steven said: ‘I’ve been thinking about this. We’re blowing up this gas station and we’re right by this bridge — do you think we could blow up the bridge? If we have the camera looking this way at Ray’s house, how about if the bridge blows over here, then all the houses blow over there, and then an 18-wheeler comes right down into the house? Can we do that?’ We already had matchmove information for the street and houses and the bridge, because we were adding cloud effects over Ray’s backyard, so I said, ‘Surre, we can do that!’”

The shot was put on the fast-track for production in late December 2004 so that it could be included in a trailer targeted for Super Bowl Sunday in early February. Helman and his team gathered additional matchmove information, while Dan Gregoire revised a 3D animatic of the shot, tracking back with the minivan as it drove away from the exploding gas station and bridge. Spielberg operated the camera. “Steven rode in front of Ray’s minivan and followed it all the way up the street,” recalled Helman. “He was really having fun. We were in the middle of the take, and he said, ‘Hey, Pablo, should I pan up to maybe see some cars coming towards us?’ I said, ‘Yeah, just do it!’”

ILM prepped the shot for the addition of elements, doing motion tracking, rotoscoping and paint effects to remove the bridge. “Five roto artists and four *Inferno* artists layered in the exploding gas station, the CG falling truck and the explosions behind that,” recalled Marshall Krasser. “At least 14 people worked on that one shot, using 200 elements on the CG side and another couple hundred in *Inferno* compositing, making probably 400 elements. The final shot was comped in *Inferno* by Chad Taylor.”

Steve Gawley’s team created an array of 1/8-scale miniatures for the bridge destruction, including a row of four houses — two crushing and one exploding — a crushable tanker truck, exploding debris and four 1/8-scale bridge supports shot with



After escaping the destruction of his neighborhood, Ferrier drives onto the turnpike, attempting to formulate a survival plan. To dramatize the character’s barely contained panic, Spielberg staged a complex shot that followed the minivan as the camera circled the vehicle, passing in and out of the passenger cabin in a

multiple cameras on the slab at ILM. “We mapped the bridge supports onto digital cards,” said Curt Miyashiro. “We built sections of the bridge in 3D and broke apart its surface using rigid body dynamics.

We took a bunch of existing 3D vehicle models, repainted them, put graphics on the trucks, and

packed them on the bridge; and then we did a lot of

simulations in Zeno and Maya to get all the movement working. We handled the tanker truck as a ‘hero vehicle’ and rendered it with multiple passes to really choreograph that motion.”

Development continued on the shot four months beyond the debut of the Super Bowl teaser trailer. “We worked out a new pipeline for the textures on the cars,” stated Krasser, “and created a better balance of specular and flashing levels, making sure we had the depth hazing working right. The plate had been shot on an overcast day, and it took a lot of hand-keying and rendering more dust to get that looking right. Steven wanted dust springing off individual cars, so that went back into the *Inferno* to get more interactions. We also added more miniature debris to the foreground, including a miniature chair that comes flying up, rotating through frame.”

Ferrier drives the van onto a highway clogged with pedestrians and abandoned vehicles incapacitated by alien electromagnetic interference. The production shot the sequence with approximately 1,000 extras on a two-mile stretch of the New Jersey Turnpike. “It was supposed to be a crowd replication shot,” observed Sandra Scott, “but when Steven saw the dailies, he realized it worked without it.”

To dramatize Ferrier’s barely contained panic while navigating traffic, Spielberg staged a complex shot that followed the minivan and circled it. Previz artist Dorian Bustamente used satellite photography of the turnpike location to plot vehicle choreography, the serpentine camera move, and dialogue timings with Spielberg. “Even though it was a dialogue scene,” Pablo Helman commented, “Steven did this animatic of the van entering the freeway, the camera traveling around, going inside the van and out again — and he kept it going for about two and a half minutes.” The apparently seamless shot actually broke down into seven pieces. Portions with the camera outside the vehicle were shot on the turnpike location, which the production had secured for a one-day shoot, without principal performers. “We worked with the second unit director and stunt coordinator Vic Armstrong to shoot the pieces that we needed with the camera outside of the van, moving in between cars and in between people walking on the freeway. We then shot the path of the van with an eight-camera array — three cameras in front, three in back, two out either side. We stitched those together to create a background for a digital environment.”

ILM used the background plates, projected onto a dome, to encompass photography of Ferrier and his children interacting inside the van on a soundstage set surrounded by bluescreen. “We matched the move of the freeway plates on the bluescreen stage, moving the camera around the actors,” said Helman. “A special effects person moved the steering wheel using another steering wheel in the fender of the car, watching playback of the background, while Tom held his hands as if he was steering.” The bluescreen set was lit to simulate daylight moving across the vehicle, shot without windows to allow a Technocrane to glide in and out. ILM added CG windows, rear-view mirror and

seamless take. Using satellite photography, Halon previsualized the vehicle’s path, a two-mile stretch of road that was subsequently covered by a stunt driver. Spielberg shot van interiors with principal performers against bluescreen. ILM blended all the elements, adding a moving 360-degree background, shot from an eight-camera array and stitched together.

windshield, generating reflections from background plates. The bluescreen car was shot without benefit of motion control. "Though it seemed like a textbook motion control shot, we took the attitude 'motion control is for wimps.' *Instead*, we spent two days rehearsing the camera, following the background. When it was time to shoot, Steven had the actors follow timings he had established for the dialogue."

A team of 14 compositors, led by Michael Jamieson, tracked and inserted the bluescreen performances into location plates, blending elements to create a seamless shot that concluded with the camera swinging out past Cruise, pulling back from the minivan to a high angle filmed on the turnpike from a mobile camera crane. "We matched the bluescreen shot of Tom to the location plate," said Helman. "We pulled the Technocrane up as far as possible, then mapped Tom and the cabin to the plate, projecting them with a Zeno camera. As Tom filled the screen, we made the transition to the crane move on location."

Ferrier attempts to reunite his children with their mother in Boston and, en route, encounters harrowing after-effects of alien attacks. *Images* included a downed 747 airliner, built full-scale on the Universal Studios backlot, a runaway burning locomotive, filmed as a 1/2-scale pyrotechnic effect at a Los Angeles railroad crossing, and corpses floating down a river, as witnessed by Rachel. The latter scene was filmed in rural Virginia, and utilized articulated latex polyfoam dummies created by Edge FX. "Spielberg was very specific about how the bodies should float," related Edge prosthetic supervisor Christian Beckman. "He wanted chests and faces to breach the surface, with an occasional hand or foot appearing. It was very tricky to balance buoyancy because these things weighed 250 pounds after they had been in the water." To simulate natural corpse flotation, lead prosthetic artist Leon Laderach cast 25 dummies with metal weights and plastic-bottle air pockets embedded in the polyfoam. On location, crew members secured each body to a metal cable and fed dummies into the river via a chute that extended over the water. After the river current carried the corpses through frame, rescue teams with Jet-skis and scuba gear retrieved the bodies downstream. "We lost three dummies, so the production alerted local authorities in case anybody found them; but, to my knowledge, they never turned up." ILM cloned and composited floating bodies to triple their number.



Ferrier and his family join a crowd of refugees, brought to a halt at a railroad crossing where a locomotive speeds by with all of its carriages blazing. Pablo Helman and special effects supervisor Daniel Sudick shot the sequence on location in Los Angeles, using a half-scale railroad car set ablaze, and filmed multiple undercranked takes of the rig passing by camera at some 30 miles an hour. Dennis Muren oversaw assembly of the train and crowd elements, which were enhanced with practical spark effects rushing past the railroad barrier.

Refugees arrive at a ferry port filmed on location in Athens, New York. Panic sets in when tripods appear on a hilltop horizon, backlit in the freezing night. "It was snowing when we shot the ferry scenes," Dennis Muren recalled. "We were shooting for five nights and the snow changed to rain from shot to shot, but it filled the sky with a lot of really neat atmosphere. We carried that over in our effects, creating this strange, almost Christmas-style beauty behind the horror and carnage."

Ferrier and his children manage to board the ferry, but another tripod appears from beneath the water. Sequence supervisor Nigel Sumner generated glowing whirlpool turbulence as a particle effect to suggest tripod interaction with the water. "We were struggling with how the whirlpool should look," related Marshall Krasser, "but then our art department pulled out some reference of the Nautilus submarine from Disney's *20,000 Leagues Under the Sea*. That exact day we had our transmission with Steven, and he said: 'You know what this is? It needs to be like 20,000 Leagues.' So we paid homage to that style."

As tripods rise from the water, Spielberg called for a new look for the machines. "We developed what we called the 'über-tripod' look," said Robert Marinic. "These were the generals in the tripod army. They were based on entirely different concept art, so we modeled a more flared-out, wider head, with a lot of shader work to make rivers of water flow off the surface."

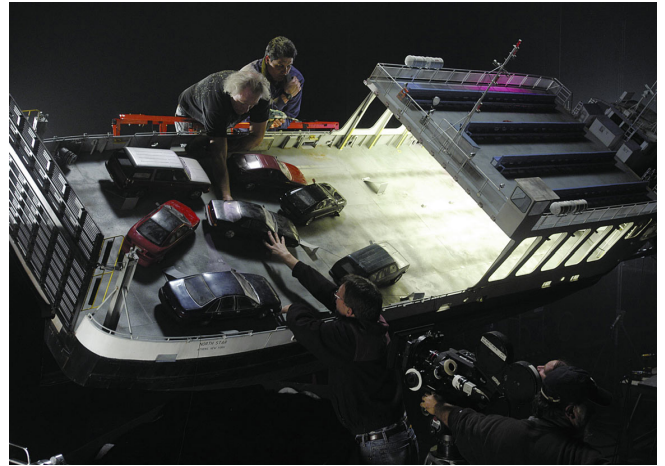
Tripods attack the ferry, capsizing the vessel and tipping passengers and vehicles into the water. Vic Armstrong's stunt team staged water-level action with principals and stunt performers enacting practical water stunts in a four-day shoot at Universal Studio's interior water tank. Wide shots of the ferry inverting were captured at ILM, using a 1/8-scale miniature. "Senior modelmakers Don Bies and Robbie Edwards and their team laser-cut the miniature boat from art department CAD drawings and photo reference of the ferry," stated Steve Gawley. "Lead miniature painter Peggy Hrastar and her team applied the photoreal paint scheme to the 21-and-a-half-foot-long, five-foot-wide ship. The hull was made of wood, with an aluminum piping armature built inside." Geoff Heron and his crew built a mechanical rig that rotated the miniature like a rotisserie, ten feet above the studio floor. "We shot it dry-for-wet, partly because the lights had to remain on as it rolled and we were having problems trying to make hot lights go into cold water and stay illuminated. Modelmaker Jon Foreman and a couple of his guys rigged high-intensity lighting on the boat to make it read at high-speed in a smoke environment."



Panic sets in when a tripod appears at a ferry port, causing the crowd of refugees to surge forward onto the boat. Spielberg staged the sequence over several nights at a location on the Hudson River in upstate New York. ILM incorporated CG tripods into the live-action photography, as well as practical rain, mist and smoke elements to augment the freezing rain and snow encountered in the shooting environment. Composites also featured tripod headlamps cutting through the gloom.

Gawley's team dressed the miniature ferry deck with a dozen 1/8-scale cars, each weighing approximately ten pounds, designed to intercut with closeups of full-scale falling cars shot at Universal. In wide shots of the ferry capsizing, compositors added digital stunt doubles, digital water simulations, layers of churning bubbles, and foreground elements of Ferrier and his children flailing in the water tank. The scene was predominantly shot from water level, gazing up at tripods as they plucked victims from the water. "Steven played the whole movie from Tom's character's POV," remarked Dennis Muren. "We very rarely cut back to show a classic Hollywood master shot. The camera was right in there in the water, bobbing up and down, and Tom was in the water with lights above him that we knew we would have to paint out. Once we were framed off Tom, we continued to tilt up with a victim being pulled out of the water — which was all CG — and then we came back down to the plate."

Following the ferry attack, Spielberg planned a brief sequence — known as 'Camelot' for its ethereal lighting design — which had Ferrier and his children entering a deserted neighborhood and then encountering a roving battalion of tripods. Spielberg shot performers on a fogged-up soundstage set. ILM expanded the environment using a miniature set, replicated in Zenviro. "Steven wanted a foggy look," said Pablo Helman. "By bringing the miniature into Zeno, we were able to create a very striking look and we created our camera moves around the tripods." Steve Gawley's team built the miniature set at 1/8 scale, two streets deep and four stories tall, covering a 20-foot-wide by 64-foot-long elevated platform. Director of miniature photography Marty Rosenberg shot low-angle background plates to match perspective of foreground elements. The camera layout department locked plates together to generate a Zenviro environment, and then compositors layered tripods with miniature fog and sky textures from stage photography. Tripod interactions, smashing into buildings and reaching



Vehicles and occupants slide across the deck and tumble into the freezing water as tripodsoverturn the ferry. The productionstaged water-level action with principals and stunt performers in a water tank at Universal Studios in Los Angeles. ILM generated allwide shots of the capsizing craft, shooting a miniature ferry andweighted miniature automobiles. Digital artists then added CGpassengers, tripods and water.



ILM practical effects teams riggedthe ferry to tip using a manually-operated rotisserie mechanism. The overturned boat was shot dry-for-wet in atmospheric smoke tosimulate underwater diffusion,which compositors enhanced with digital elements, bubbles and flailing bodies.

inside, were created using interactive miniature lighting effects combined with digital and miniature debris and animated victims, including a 3D flight of birds and an unlucky French poodle. “Sadly,” said Gawley, “the sequence was cut for time from the film in the last weeks of postproduction.”

Ferrier and his family next cross the countryside into a combat zone where the military is mounting an assault on tripods from a hilltop vantage point. The production staged the valley war on rural locations in Lexington, Virginia, and Piru, California, using infantry and tank battalions from local Army and Marine Corps units. “The location in Virginia was very cold and very complicated to light,” noted Pablo Helman, “so we decided to split the sequence and do some of it in California. The art department did a great job of dressing the California set. It was impossible to tell we were in two completely different locations.”

Spielberg initiated the valley war shoot at dusk, tapering into nighttime. The physical effects crew provided pyrotechnic effects and flash bars on cranes to simulate tripod attacks and military response; but all airborne hardware and ordnance were modeled and animated digitally. “We created tons of helicopters, F-22s, F-16s and A-10 Warthogs,” recalled Curt Miyashiro. “A lot of pyro was practical, but sequence supervisor Raul Essig and his crew filled it out with explosions and CG smoke trails.”

At the climax of the skirmish, soldiers charge over the hill and tripods retaliate, raising a giant wall of flame — an effect created largely in-camera. “Dan Sudick’s team planted 40 mortars along the hill,” said Helman. “We set up four cameras, including one with a 14mm lens looking right into the heart of the explosion, then Dan’s team released fuel into the air and lit it, creating a wall of flame 400 feet high that lasted about four and a half seconds.” ILM supplemented flames on the sides of frame and extended burn duration as a towering über-tripod emerges through the fire. Compositors inserted the machine using depth displacements and additional pyrotechnic elements to wrap around the tripod, slowly revealing the monster as it emerged unscathed.

Humans scatter across the hillside, seen in a wide shot constructed from multiple elements shot on two coasts. “The last shot of the sequence was a slow tilt-up to reveal three tripods advancing,” stated Helman. “We had planes firing weapons, explosions hitting tripod shields and people running down the mountain towards a farmhouse. The part with the house was shot in Virginia with a bunch of people running by. The hillside was a digital matte painting projected onto geometry, and we animated three tripods onto that.” ILM crew members portrayed refugees, shot day-for-night on video on a hill at Skywalker Ranch, then color-corrected to the nocturnal lighting palette. “In the conceptual artwork, lighting was originally coming from below the tripods from the



Ferrier and his children survive the attack on the ferry and – in a sequence cut from the theatrical release of the movie – encounter a roving battalion of tripods in a deserted neighborhood. Known as ‘Camelot’ for its ethereal lighting design, the sequence was shot with principal performers on a fogged soundstage set. ILM expanded the environment using a miniature set, mapped and projected digitally in Zenviro. Artists introduced 10 animated tripods into the digital environment and created camera moves with creatures looming over Ferrier and family, reaching through buildings and interacting through atmospheric fog effects.

fire on top of the hill. Steven preferred to keep the tripods mysterious, so we changed the lighting to make them completely backlit. That was what was different about this movie: it was not about the aliens, it was not about the tripods, it was about the people. This sequence was about a father trying to hold onto his son, who wants to go to war, while also trying to protect his little girl. In this shot, we saw how strong those conflicts were.”

Separated from his son, Ferrier and his daughter take refuge with survivalist Harlan Ogilvy (Tim Robbins) in a farmhouse cellar, as aliens busy themselves above, propagating their species by cultivating an alien fungal growth. Stan Winston Studio and the physical effects team produced red weed as practical set dressing based upon concepts by Doug Chiang’s design group and Winston designer Aaron Sims. “We didn’t get involved until three weeks before they started shooting,” said Lindsay Macgowan, who shared supervisory duties at Stan Winston Studio with Alan Scott. “We had the least amount of prep we’ve ever had on a movie, but we built miles of red weed and the little embryo pods it grows from. It was tricky. This was a science fiction movie, but it was also a drama. It was difficult to make glowing red weed look cool without being too retro.”

A crew of 60 artists generated red weed in a variety of sculpted forms, from intricate striations to eight-foot-wide coral-like branching pieces, molded and cast in red-tinted urethane, then painted and assembled in modular sections. Closeup weed was cast in silicone and lit internally by fiber optic filaments, powered by projector lamps hidden beneath the soundstage set. A last-minute revision altered the introduction of the weed, which had been dressed across a meadow set rigged with 150 liquid-filled, illuminated pods containing animatronic embryonic aliens. “We had the pods all ready to go,” related Winston special effects coordinator Shane Mahan, “and Steven liked what he saw; but I think he felt it took the audience out of the reality of the drama, so he cut the sequence.”

The fungus is instead revealed as Ferrier peers out at tripods harvesting humans to feed the weed, which gestates as blood spatters on a window sill. Stan Winston Studio dressed the window set with a urethane weed tendril stippled with red-tinted latex, rubbed to create fibrous tendrils and spritzed with water and K-Y jelly. ILM then enhanced the element with digital animation. “Steven wanted the weed to ‘metastasize’ like a cancer growth,” explained Curt Miyashiro. “We sampled textures, made branches procedurally into a tree-like structure, and used paintwork and subsurface scattering to make it look translucent.” Wide shots of the weed covering landscapes were generated as digimatte paintings blended with live-action, rendered with a subtle glow. Daniel Sudick’s team



The Camelot environment was based on photographic reference of a location in Newark, which featured two-story buildings. ILM miniature supervisor Steve Gawley constructed the miniature with four-story dwellings to better accommodate a dramatic reveal of the tripods through the mist. The set covered two city blocks, filling a 20-foot-wide by 64-foot-long area on an elevated platform that allowed director of miniature photography Marty Rosenberg to shoot low-angle background plates that matched the street-level perspective of human performers. Modelmakers Carol Bauman and Danny Wagner detail the street surface with miniature debris.

created additional filler weed that the production 'greens' department intermingled with Winston weed on sets and locations.

Tension mounts as an electronic tripod eye on a long metallic probe searches the cellar. Pablo Helman oversaw the visual effects for the sequence, including the computer-animated tripod probe. Spielberg made use of a detailed animatic of the sequence using a 3D model of the cellar set and a stand-in prop to give the performers a sense of the probe's placement and inquisitive nature. "The probe was an information-gathering tool for the aliens," said Randal Dutra. "We controlled its rate of progress, the attack and decay of its movement, how it came around a corner, paused and reacted to its environment. It was very interactive, with onboard lights glowing and dimming as if the tripod's interest was waxing and waning. We wanted to suggest an intellect."

Janusz Kaminski lit probe effects plates without atmospheric smoke to allow for more dexterous composites, but the dramatic lighting palette of different colored pools of light proved deceptively difficult to match when inserting the reflective CG creature. Compositing sequence supervisor Pat Brennan and his team generated animated garbage mattes to isolate sections of the probe, preserving densities of black as the creature emitted internal glows and reflected a wide-angle mirror dome of the set in its large unblinking eye. To create effects of lights emanating from the probe, compositor Jeff Doran blended volumetric light beam renders, occlusion passes, lens flares, blooming light sources and practical illumination. "Pablo did a walk-through on set with a pair of practical lights," explained Curt Miyashiro. "Whenever possible, to root shots in reality, we matched our computer generated lighting to real illumination on the wall or floor."



After his son runs over a hilltop to join terrestrial militia, Ferrier is terrified by the spectacle of a giant wall of fire engulfing the area, shortly followed by an über-tripod that emerges through the flames. The physical effects crew rigged the pyrotechnic event on location using an array of mortars to create an in-camera wall of flame that measured 400 feet high and lasted roughly four and a half seconds. ILM supplemented flames on the sides of frame and extended the burn duration. The über-tripods, which featured a more flared-out head, represented generals in the tripod army.

The probe silently retreats and four aliens appear to explore the cellar. Alien creature design required intense development by the ILM art department, Ice Blink and Stan Winston Studio, and finally took shape in a rendering by ILM creature designer Carlos Huante and by the 3D modeling team led by Michael Koperwas. “We took the idea of the triangle that runs through the alien culture,” remarked Dennis Muren. “The creature had three legs, three fingers and a triangular-shaped face — everything had that triad theme.”

ILM used a full-size alien maquette to block scenes on set, guided by animatics and Spielberg’s verbal cues. “Steven used his director’s bullhorn to vocalize the aliens,” noted Pablo Helman. “He’d call out, ‘Ullaa!’ A couple of times he sang the *Jaws* theme — ‘daa-dum, daa-dum.’ Janusz Kaminski lit the scene to keep the creatures very mysterious, which made them a lot of fun to light in CG, keeping the characters rim-lit, with strong highlights and cucaloris effects.” Alien skins were rendered with subsurface scattering to create a delicate, clammy translucency. Eyes were given a moonlit, glazed expression detailed with cornea, caruncular and inner geometry, and a refraction shader designed to react to highlights. Subtle composite effects included alien footfalls in puddles and interactive puffs of dust.

Spielberg made use of the environment to reinforce the creatures’ presence, partially obscuring aliens behind objects and cueing physical effects as creatures picked their way through clutter, wafting past hanging drapery and spinning the wheel of an old bicycle hanging on a wall. Alien behavior was patterned after amphibian reference that characterized the alien’s stealthy, but simple-minded nature. “Steven was after very nimble fingers and toes,” said Dutra. “I pictured them moving very creepily, close to the ground, so I studied red-eyed tree frogs, how they use their fingers to grasp and negotiate their space. In one shot, an alien passed through a narrow hallway, so we had the hands plant on the wall instead of on the ground and then the third leg planted down as a surprise. It was a very amphibian nuance. Any time an animator can start with an organic reference, it allows him to explore some neat behavior while keeping it believable.”



Ferrier and his daughter, Rachel (Dakota Fanning), take refuge in a farmhouse cellar, where their safety is jeopardized by a probing electronic tripod eye on a stalk. Spielberg planned the cellar sequence using detailed 3D previz. On set, Pablo Helman walked a lighting rig representing the probe through the shots, which director of photography Janusz Kaminski lit without atmospheric smoke to allow for more dexterous compositing of the CG probe and interactive lighting effects.



After the probe retreats, four inquisitive aliens appear – generated by ILM as digital characters rendered with subsurface scattering to create a delicate, clammy translucency on the skin.

Aliens retreat, but a tripod returns to abduct Ferrier's daughter. The sequence involved location and soundstage photography shot with practical interactive tripod light and a tripod undercarriage and mechanical baskets — where the aliens store their victims — built by the art department and physical effects. "We shot that in L.A.," stated Dennis Muren, "using a motion base rig that Dan Sudick's people built to make the baskets move around."

ILM updated the tripod model for the abduction scene, adding two rear-mounted collection baskets. The team also created a digital double of Dakota Fanning, seen in a wide shot as the tripod seizes the tiny girl and deposits her in its basket. Ferrier hurls a hand grenade at the tripod, which explodes harmlessly against the creature's invisible defensive shield — an *Inferno* effect created by combining mattes with 3D shield geometry and pyrotechnic elements — then is hauled aloft to find his daughter catatonic among a knot of other captives in the tripod basket. A tentacle next appears through an aperture above the cage and drags victims into a fleshy sphincter in the tripod underbelly. To shoot the scene, the physical effects crew pulled a stunt performer through a mechanized opening in a wall of textured silicone generated by Stan Winston Studio. ILM animated the tripod tentacle and replaced the practical underbelly with a fleshy undulating texture, animated to suck and constrict around the performer.

To escape a similar fate, Ferrier grabs two grenades from a fallen infantryman and releases them inside the tripod maw, causing the war machine to detonate internally. "The tripod implosion was a light show of explosions and colors," commented Michael Di Como. "Dennis joked that we didn't know what they had inside there, a nuclear reactor or a refrigerator, so we added a lot of interesting textures, with green energy leaking out. The explosion was inspired by a practical element of steel wool on fire. We replicated that in a procedural version to create this otherworldly material burning inside, composited by Jeff Sutherland and his team." Explosions rip the tripod apart, shaking loose the basket, which lodges in a tree as the war machine slams into the ground — achieved using a miniature stage element. "We wanted to see a massive amount of dirt and pyro flying up, so Steve Gawley's team built a big expanse of dirt and blew it up. That gave us this beautiful combination of fire surrounded by flying dirt. A lot of times the best way to get that kind of interaction is just to shoot it."

Ferrier and his daughter continue to Boston, where soldiers attempt to herd refugees away from a tripod teetering erratically between high-rise buildings. Dan Gregoire prevized the sequence using a 3D model built from 600 photographs and satellite surveys of the shooting site in Clarkstown, New York, allowing Spielberg to plot camera angles. ILM added a giant half-fallen tripod — its occupants defeated, not by military firepower, but by unfamiliar germs — embedded into a building as a digimatte painting, composited with aerial haze and circling birds integrated into daylit plates.



As the film draws to a close, Ferrier and his daughter witness one of the once-invincible tripods being toppled by the military as its occupants fall victim to earthborn

The tripod, vulnerable without its protective shield, is fired upon and crashes into a factory, created as an interactive miniature element. “Senior modelmaker Charlie Bailey and his team built the front of the factory at 1/12 scale,” Steve Gawley explained. “As the tripod fell, it grabbed two chimneys with its tentacles, went through the brick façade, and then its head came skidding up to camera.” Kim Marks shot the factory miniature on the ILM slab, while Geoff Heron’s team engineered the collapse using a ten-by-seven-foot mechanical bluescreen rig that crashed through the factory façade. Senior modelmaker Michael Lynch oversaw construction of two 1/12-scale, 150-foot brick chimneys, which were photographed as separate elements, rigged to come apart brick by brick, filmed high-speed. Compositors blended the miniatures into live-action factory side walls, generated CG tripod damage with hand-painted texture maps, and added a practical mist and steam element tracked to the falling machine, with a splash of liquid hitting the camera lens on impact.

Soldiers and civilians approach the fallen tripod — a 25-foot-tall, 35-foot-wide full-scale head built by Stan Winston Studio and filmed on the backlot at Universal Studios. “Ice Blink provided us with a Maya file,” said Lindsay Macgowan. “We broke that into sections and milled it out of urethane foam. We fitted eight foam pieces over a metal frame, smoothed down surfaces, sculpted the lines, hardcoated the foam, prepainted the pieces at our studio and added a hydraulically-controlled tripod door that had ten points of computer-controlled motion. We then assembled it at Universal with Dan Sudick’s team, which added a dump tank at the top.”

The opening door emits a flood of amber fluid, followed by an alien limb, echoing the closing scene of the 1953 film. “The alien hand was an iconic image and homage to the earlier movie,” said Pablo Helman. “But it also fit with the theme of Steven’s films. Previously, his aliens have always been benevolent — and here we were now showing this alien culture arriving to kill us. The movie certainly polarized characters against the aliens, which were very frightening, but this was never intended to be a gory encounter. My feeling was this had to do with the message that Steven wanted to communicate: the reason these aliens come to earth is that they don’t have anywhere else to go. Their planet is gone, they are trying to survive; and so, in the end, we feel sad. We don’t feel satisfaction in seeing this creature die.”

Spielberg gave directions to underline the pathetic nature of the alien’s death, incorporating a gesture improvised on set. “On the spur of the moment, Steven had a soldier come up and use his gun barrel to lift the alien hand, then drop it,” recalled Randal Dutra. “The camera then panned back up to the alien as our atmosphere broke it down. It was a great visual gesture that showed this earthling making one final test to see if earth would be safe again; and when that hand dropped harmlessly, we knew the alien race was dying. It was a very powerful shot.” ILM animated alien vocal chords to shake and constrict, and hunched the creature’s shoulders as it released its final breath and visibly transformed. “We created new paintwork to give the skin a desaturated and chalky look,” said Curt Miyashiro. “We also wrote some shaders for its eyes, crystallizing and fogging up the lenses as the alien passed away.”

organisms against which they have no immunity. Halon previsualized the sequence using a 3D model built from 600 photographs and satellite surveys of the shooting location in Clarkstown, New York. ILM animated the tripod teetering through buildings and composited the crippled machine with aerial haze and circling birds, inserting it behind a factory building as soldiers open fire from below.

ILM produced 239 visual effects shots for *War of the Worlds* — a seemingly modest number in the wake of the recent *Star Wars* saga, until viewed in light of the film's 45 minutes of visual effects screen time and 123 character animation shots. "The real factor here was the complexity of shots completed on a postproduction schedule of only 12 weeks," stated Sandra Scott. "At no point did that time-frame hinder Steven, Dennis, Pablo or any of the crew. No one ever uttered, 'We can't do that, we don't have time.'"

The project represented a baptism of fire for ILM's new production pipeline, on the cusp of relocation to new premises at the Letterman Digital Arts Center in San Francisco; but, viewed from a historical perspective, the rapid turnover was not unheard of in the facility's 30-year experience. "Look at *Ghostbusters II*, almost 20 years ago," noted Dennis Muren. "That started shooting at Thanksgiving, and we were done by around July 4 — but that didn't mean that everybody suddenly was making films that quickly. Most people understand that the more time you give a show, the more likely it is the results will be better. Having said that, this was a great example of how to get a film done well on a short schedule. Steven and everybody knew they were pushing it; but the work still turned out well because ILM and the live-action team had worked together successfully many times before. Plus, we were working with someone who was experienced and confident in his own vision. That was so important."

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The alien war machine topples forward, grabbing two 150-foot chimneys with its tentacles as it slams through the factory building, crashing into closeup. Using data and photographs from the set, the ILM miniature effects team re-created the factory façade and the chimneys as separate models, rigged to collapse and shot on an outdoor bluescreen stage at high-speed. Compositors blended the miniatures into live-action factory side walls and added CG tripod damage via hand-painted texture maps, practical mist and steam, and a splash of liquid hitting the camera lens.



The alien war machine topples forward, grabbing two 150-foot chimneys with its tentacles as it slams through the factory building, crashing into closeup. Using data and photographs from the set, the ILM miniature effects team re-created the factory façade and the chimneys as separate models, rigged to collapse and shot on an outdoor bluescreen stage at high-speed. Compositors blended the

miniatures into live-action factoryside walls and added CG tripoddamage via hand-painted texturemaps, practical mist and steam, and a splash of liquid hitting the camera lens.

Starting Over

image

ARTICLE BY JOE FORDHAM

D.C. Comics' bat-masked, crime-fighting millionaire Bruce Wayne has been adapted, reinvented and re-imagined in a variety of media, with diverse takes on the persona introduced by Bob Kane in 1939. Director Tim Burton gave the hero a brooding, gothic twist in 1989, kicking off a run of four Warner Brothers *Batman* pictures produced over the next eight years. The series faltered after the *Dark Knight* — clad in a batsuit infamously equipped with 'bat nipples' — tangled with a trio of campy villains in Joel Schumacher's *Batman and Robin*.

This summer, the franchise was revitalized with *Batman Begins*, an exploration of the genesis of Wayne's mythos, presented in a stripped-down, utilitarian manner proposed by director Christopher Nolan. The new take on *Batman* comic book lore was evident in the earliest discussions with visual effects providers. "My first meeting with Chris was in his garage in his house in Hollywood," recalled visual effects supervisor Janek Sirrs. "Production designer Nathan Crowley was sweating away in 90-degree heat in an un-air-conditioned garage, building a model batmobile using parts from plastic model kits. It was very clear, even from that 14-inch maquette, that this *Batman* was a guy who built and acquired his gadgets as functional items. There were no 'magic powers,' no forces from another planet. Everything was grounded in reality."

The screenplay by Nolan and David Goyer follows *Batman* (Christian Bale) from his traumatic childhood, witnessing his parents' murder, through martial arts training in the Far East, to his return home to Gotham City where psychiatrist Jonathan Crane (Cillian Murphy) is facilitating a crime-spree for a mysterious unseen master villain. Wayne combats Crane's nefarious plot as *Batman*, counseled by his butler Alfred (Michael Caine) and Wayne Industries science advisor Lucius Fox (Morgan Freeman), who develops *Batman's* gadgetry.

A key ingredient to rooting *Batman Begins* in the real world was a modern, urban setting. Co-visual effects supervisor Dan Glass joined Janek Sirrs in early preproduction to plan a location shoot in Chicago, which set the tone for Gotham City. Selected Gotham landmarks would be shot on location in England where the production was based. For more complex nighttime street scenes, the production built an expansive set inside a *World War I* dirigible hangar in Cardington, Bedfordshire. "Cardington was the second biggest freestanding interior space in Europe," said Sirrs. "The local fire brigade had built four buildings inside for training, one of which was eight stories tall. It was the perfect foundation to build a movie on." The Gotham City set included buildings, streets and alleys that incorporated the hangar's structural supports, allowing wide shots to be achieved in-camera, without greenscreen backings.

Nolan's intention was to extend the real-world sensibility of his Gotham City to every element of the film. "Chris Nolan wanted to design highly ambitious shots and stunts," commented Dan Glass, "but he wanted to achieve as much as he could in-camera, which was quite refreshing."

The approach to physical effects was also far from formulaic, with Nolan announcing early on that he would not be utilizing a second unit. “Traditionally,” stated physical effects supervisor Chris Corbould, “if you’re doing a big action film you have a second unit shoot most of the action, then first unit comes along and shoots the actors. Chris did it the other way around and shot action sequences first unit, which was a novel approach.” Stunt coordinator Paul Jennings and Corbould’s team of 60 engineers and technicians conducted extensive tests to establish stunt choreography in advance of the location shoot, developing a rapport with the director and laying down action ground rules. “Chris didn’t want giant explosions with cars blowing up with thousands of gallons of fuel. He wanted a ‘crunch factor’ — if a car hit a concrete post, the steel folded up and buckled so the audience really felt it. Physical effects guys have a tendency to make everything bigger, brighter, more ‘over the top.’ Chris reined everything in until it was absolutely believable.”

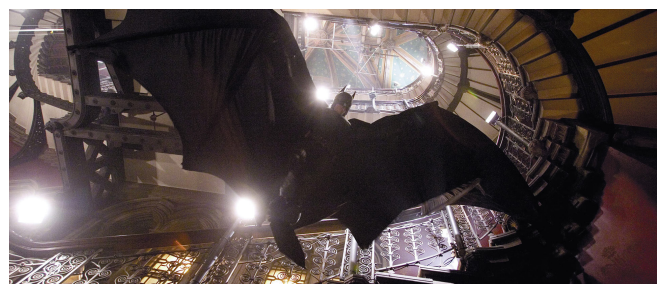
Despite Nolan’s commitment to live, in-camera work, aerial shots of Gotham and more extreme action sequences would require miniatures — provided by Robbie Scott’s Cutting Edge and shot by miniature effects supervisor Steve Begg — as well as digital effects led by Double Negative, which focused on all things Gotham and developed technical resources. Additional vendors included The Moving Picture Company and Buf Compagnie.

Animatics created by a five-person Double Negative previsualization department, led by CG supervisor Dayne Cowan, were used sparingly to plot visual effects plate photography in England and Chicago. “This was not a film where previz was used to plan every visual effect from the outset,” observed Janek Sirrs. “Chris Nolan wanted to shoot as much practically as possible, and visual effects only came to fruition as time went on. Rather than jump out of the gate too quickly, we had to bide our time and lay the groundwork. We didn’t realize how beneficial that would be until the very end.”

Bruce Wayne’s transformation into *Batman* starts with a prologue that interweaves Wayne’s memories of childhood with his experiences training at an obscure mountaintop retreat under the enigmatic Henri Ducard (Liam Neeson). Himalayan vistas were shot in *Iceland*, where unseasonably mild temperatures required Chris Corbould’s team to enhance shots with flurries of paper snow.

Wayne’s arrival at Ducard’s retreat features an aerial shot revealing the ancient monastery perched on the glaciated mountainside. The production constructed a façade of the monastery gates on location as a full-sized set capable of withstanding high winds. The establishing shot was then photographed as a helicopter plate, into which Double Negative later inserted a miniature monastery based on a dramatic maquette built by the art department. “The maquette was a very precipitous ravine with buildings clinging to the rock,” related Double Negative visual effects supervisor Paul Franklin, “but the location in *Iceland* was a much gentler slope.”

To reconcile the design to the location plate, Double Negative matchmoved the *Iceland* aerial plate in boujou, then lead programmer Jonathan Stroud developed software to map terrain locators to a 3D surface. “We used that geometry to plot a motion control shoot with the miniature,” said Franklin. “We also created our own digital version of the maquette



to work out a layout for the monastery buildings and dressed surrounding rocks by carving into the mountain in Maya, preserving edges of the 3D patch from the *Iceland* footage. We then took our terrain patch, chopped it into profiles and supplied the data to Cutting Edge, who used that to construct their miniature terrain.”

Cutting Edge built the miniature mountain as a metal frame clad with wire and plaster sheets, detailed with texture stamps made from sheets of natural rock. The monastery was built at 1/24-scale using mainly pine timber with plaster roof tiles stained a terracotta color. Double Negative exported the camera move from the *Iceland* plate to a Milo motion control camera move, then nested the miniature element into the plate and enhanced the shot with digital flags, smoke plumes and Maya snow simulations matched to natural falling snow in the preceding shot.

Monastery interiors were constructed at Shepperton Studios for scenes in which Wayne undergoes martial arts training. The training sequences were shot with minimal wire rig effects. “There were no wire assists for high kicks,” noted Janek Sirrs. “The fighting style was very gritty, and the only times we used wire rigs were for safety or as jerk-rigs for explosion shock blasts.”

After a fight between Wayne and Ducard’s followers ignites a gunpowder cache, the mountaintop sanctuary is obliterated. The explosion effect was initially planned as a full-scale mechanical collapse to be shot at Shepperton using large hydraulic rams. Budgetary issues caused the effect to be reconceived as a one-take event improvised by the physical effects crew. “The set was built from solid timber beams,” recalled Chris Corbould, “so after we made sure Chris Nolan had finished shooting all his other scenes, we spent a day chain-sawing and lacing it all up with explosives. Chris positioned eight or nine cameras around the set and we trashed the place. We couldn’t let anybody inside during the explosion because there was wood flying around. When Chris came in after the dust settled he laughed his socks off because the set was like a load of matchsticks.”

For exterior views of the explosion, Robbie Scott’s team constructed a 50-foot-wide, 1/6-scale monastery and mountainside, the building dressed with balsa breakaway sections. Miniature unit special effects supervisor Peter Hutchinson then rigged the structure for an exterior pyrotechnic shoot. “Peter and his crew ran a multi-kaboom event that blew the miniature to smithereens,” remarked Steve Begg. “We detonated it the old-fashioned way, using a nail board, and filmed it with four cameras at 150 frames per second, using anamorphic lenses. It’s quite unusual to shoot miniatures anamorphic, but we didn’t have a VistaVision camera that would shoot fast enough. Luckily, we were blessed with

Eight years after his previous cinematic appearance, D.C. Comics’ bat-masked crime-fighter Bruce Wayne (Christian Bale) returned to movie theaters in *Batman*, a stripped-down, utilitarian incarnation of the comic realized by director Christopher Nolan and screenwriter David Goyer. Nolan favored a tactile filmmaking style, shooting on locations in Chicago, Iceland and England, and on giant sets built inside a dirigible hangar outside London. Chris Corbould supervised extensive physical effects, while visual effects supervisors Janek Sirrs and Dan Glass oversaw miniature work by Cutting Edge and digital effects by Double Negative, The Moving Picture Company and Buf Compagnie.



Bruce Wayne initiates his transformation into Batman at a Himalayan mountain retreat. The production filmed Christian Bale arriving at a monastery gates façade, built on location in Iceland. Double Negative matchmoved the aerial photography, extracted 3D data and developed a rough 3D model of the monastery clinging precipitously to the mountain. Cutting Edge used the 3D data to build a 1/24-scale miniature monastery and surrounding rock. Double Negative exported the camera move from the

great weather, which gave us sufficient depth of field. We shot it in three takes and got some terrific stuff. It was one of the first effects we tackled, and I think it gave Chris Nolan confidence in what we were doing.”

The story moves to Gotham, where Wayne adopts his crime-fighter persona, using rugged military body armor developed by Wayne Enterprises as his batsuit. “A problem with previous batsuits,” noted Janek Sirrs, “was that they had been too heavy and inflexible. Any time *Batman* tried to turn his head, he had to make a very stiff-backed motion, rotating his shoulders. The costume this time was much more like a neoprene wetsuit, which allowed for greater range of motion.”

To create the batsuits, costume designer Lindy Hemming consulted with prosthetic effects designer Nick Dudman, a veteran of Tim Burton’s *Batman* team. “The batsuit involved a lot of the processes that we use in prosthetic effects — sculpting, molding, foam rubber,” said Dudman. “I recommended fabrication supervisor Day Murch, who had worked on the batsuits on all the other *Batman* movies, and sculptor Julian Murry, who I had worked with on the third and fourth *Harry Potter* films, to work with the director in sculpting the suit.” Dudman’s crew produced lifecasts of Christian Bale, which Hemming’s team used to construct the batsuit.

Hemming also oversaw the construction of a distinctive but functional batcape. “Chris Nolan went very much with the ethic that *Batman* had real gravity,” observed Dan Glass. “The most he could do is glide using his cape, which was made of a ‘memory fabric.’ The cape hung loose, but had ribs that resembled the skeletal structure of a bat’s wings. When an electrical current ran through it, the ribs became rigid, the fabric snapped into shape and held it taut, allowing him to glide like a hang-glider.”

Physical effects supplied a batcape rig that allowed the wearer to personally activate memory fabric during a performance. “We came up with air membranes that were sewn into the fabric,” said Chris Corbould. “Christian or the stunt performer had a little compressed air bottle on his back. He could walk along with the cloak hanging loosely; but when he put his arms out and triggered the compressor, the membranes filled with air and stiffened to form a wing. It was a neat little unit because, although it was originally designed just to get the wing inflated, we ended up using it for a lot of the wire rig flying. When we were flying *Batman* in among narrow lanes between buildings, the air membrane held its shape; but if he clipped the side

Iceland plate to a motion control cameramove and blended Bruce Wayne initiates his transformation into Batman at a Himalayan mountain retreat. The production filmed Christian Bale arriving at a monastery gates façade, built on location in Iceland. Double Negative matchmoved the aerial photography, extracted 3D data and developed a rough 3D model of the monastery clinging precipitously to the mountain. Cutting Edge used the 3D data to build a 1/24-scale miniature monastery and surrounding rock. Double Negative exported the camera move from the Iceland plate to a motion control cameramove and blended miniature, practical and digital elements, including CG prayer flags, smoke and snow.



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of a building, it folded back and then resumed its shape, without spinning him around.”

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Bale and stunt double Buster Reeves performed wire rig flying stunts in the Cardington set and on location in the disused Midland Grand Hotel in Saint Pancras Station, London, which served as the interior of Arkham Asylum where Crane experiments on criminally insane residents. *Batman* infiltrates the Asylum in a dramatic rescue sequence, employing his cape to descend the well of a grand staircase, shot in-camera with Reeves on a computerized winch.

More gravity-defying shots of *Batman* plummeting from buildings or gliding over streets required digital animation, generated by Double Negative. “Chris knew early on that there would be instances where we had no choice but to use digital animation,” related Dan Glass, “so we set about creating a proof-of-concept, developing a digital *Batman* that was very real.”

To provide reference for the digital *Batman* test, director of photography Wally Pfister shot footage of Bale in costume on location, landing in a squat position, then standing and walking off. Double Negative crews, who also shot video of the scene from multiple witness cameras, developed their CG model from cyberscans of Bale in the batsuit, captured on location by Eyetronics, with supervising technical director Martin Parsons building a comprehensive anatomical rig. Digital artists roto-scoped witness camera footage of Bale’s performance, then animators used the motion as reference for keyframe animation, overseen by animation supervisor Colin McEvoy. Subsurface scattering simulated the high-contrast translucent qualities of Bale’s face.

To replicate the look of the batsuit, shader developer Samson Cowe and his team created a powerful bi-directional reflectance distribution function shader. “It was similar to the technology used on the *Matrix* sequels,” commented Paul Franklin, “but we built our own home-brew BRDF rig derived from papers published at Siggraph and scans of all the different batsuit materials.” Security surrounding batsuit design required Double Negative to work from small swatches of materials, which Franklin interpreted to piece together the digital model and construct shaders simulating the subtly reflective qualities of the suit. The cape was rendered with a flocked velvet finish on the outside and a textured nylon effect across the interior. A Syflex cloth simulation created high-frequency cape flutter.



Returning to Gotham City aboard his private jet, the long-absent Bruce Wayne observes the troubled metropolis below. The aerial sunrise became a proving ground for effects techniques used to depict wide views of Gotham. To establish the urban layout, production built and videotaped a 15-by-25-foot maquette of the city. Using that test as reference, Double Negative laid out 3D city blocks and textured buildings with imagery of Chicago architecture captured during an extensive location survey shoot. The entirely digital vista – which included CG water, atmospheric effects and street traffic – contained more than half a million buildings.

Split-screened side by side with Bale, the CG *Batman* test proved the digital double’s viability for use in key sequences throughout the film. Reality-based, tactile reference for such scenes was acquired whenever possible. “At one point,” Franklin said, “*Batman* dives down into the fog-filled chasm between buildings with his cape streaming out until it pops out into the wing shape. That was our digital *Batman*; but we were lucky enough to have

Christian's stunt double perform a wire-drop for us. Buster climbed onto one of the larger structures in Cardington, dove off on a wire, and we shot it with ten witness cameras from a variety of angles to get a feel for the action. The stunt was a lot slower than our digital fall, but it served as a good reference for how the cape was streaming in the wind. That was key. Everything we did digitally was based on real-world reference. Chris was not interested in seeing anything completely imaginary." The digital *Batman* was ultimately featured in 20 shots.

Like the batsuit, the batmobile — Bruce Wayne's most visible hardware item — was given a new look to distinguish it from previous interpretations. "Essentially, previous batmobiles have been rolling props," noted Janek Sirrs. "They were beautifully made props; but they were not performance vehicles. This time, the batmobile was built to be a performance car racing through the streets of Chicago, doing leaps, then landing and swerving through traffic and coming out relatively unscathed. It was a remarkable piece of engineering by Chris Corbould's team."

Batmobile construction closely followed the maquette design, which suggested a lethal all-terrain vehicle with stealth-technology lines and giant, chunky rear tires. "The batmobile was like a Lamborghini Countach crossed with a Special Forces attack vehicle, inbred with a Formula One," commented Corbould. "It used some existing interior components, but was built from the ground up. My mechanical engineer, Andy Smith, and his crew figured out the chassis and engine configuration, gearbox and suspension. The front suspension was very strange. There was no front axle, and there were two sub-axles coming off each wing, which gave it a unique look, like an animal sitting up on its haunches. When it was weaving in and out of the traffic, it was almost like it had a pair of shoulders."

The art department hand-sculpted the batmobile body as a full-sized polystyrene replica of the maquette. Corbould crewmember Richard Gregory then supervised pattern-making, molding, casting and fitting polycarbonate exterior panels to the chassis. Workshop supervisor Kevin Herd implemented various mechanical devices, including aerodynamic flaps, working armament and a jet engine nestled between the four rear tires. "We looked into using a real jet engine," noted Corbould, "but we backed away from that because our batmobile was going to be crashing through sets, jumping and landing. One thing I didn't want was a great long flame that curled up at the end, so we used a very short, fierce flame, a bit more colorful than a real jet engine, created with a mixture of propane and high-pressure air."



Early-morning sun illuminates Wayne Tower. Double Negative generated the 900-foot-tall art deco building from textures of the Chicago Board of Trade, and tracked the 3D structure, its surrounding buildings and a subtle glimpse of the Gotham City monorail into the Vistavision background plate shot on location in Chicago. Artists simulated naturalistic daylight on synthetic structures using high dynamic range images of location source material mapped to lighting cards positioned around the 3D model. A separate indirect diffuselighting pass allowed compositors to finesse the final look.

Batmobile safety measures included automatic fire extinguishers, with roll cage, chassis and suspension constructed to exacting specifications. "Test jumps showed us where the weak points were," Corbould said. "We strengthened it, jumped it again, saw where the next weak point was."

Additional tests of the batmobile, which was powered by a 350-horsepower Chevrolet engine, established a jump speed of 50 miles per hour from a five-foot ramp, enabling the vehicle to leap 60 feet and then continue driving. “Chris was adamant this had to be a performing batmobile. He didn’t want to have to cut around it.”

Corbould’s team created four batmobiles and one non-mechanized version. Multiples allowed for swift turnarounds if vehicles became damaged while veteran Bond film stuntman George Cottle drove the vehicle through downtown Chicago. “We had George’s and Paul Jennings’ input through the testing phase,” stated Corbould. “We knew they were going to make us look good, so we incorporated everything they needed to give us the best chance for pulling off the stunts. George made our batmobile dance!” Batmobile driving required mastery of the limited view through slot-like forward windows. Corbould’s team operated peripheral vehicle functions of rear jet, guns and flaps by radio control, while providing Cottle with hardwire overrides.

The batmobile makes its appearance on the streets of Gotham in a high-speed nighttime chase filmed along Lower Wacker Drive and a disused Chicago freeway. “This chase wasn’t done at 20 miles an hour undercranked to make it look faster,” said Corbould. “This was driven at full speed, weaving in and out of traffic at sometimes 90 miles an hour, being chased by an ML55 Mercedes camera car that had trouble keeping up. When we were driving around city blocks, being chased by a helicopter flying in between the buildings, it was breathtaking.”

Shots of Wayne at the batmobile controls were captured on a 25-percent-oversized set, mechanized by Corbould’s team and shot on a gimbal against greenscreen. To capture views of Gotham zipping by the tiny windows, production rigged a ‘platemobile’ process trailer with Vistavision cameras mounted on a high-performance truck. Rising Sun Pictures blended platemobile plates into batmobile windows with interactive lighting effects. “There were a great quantity of backgrounds that changed through the course of the chase,” remarked Janek Sirrs. “Rising Sun added flashes of light to cue with the background, raindrops and dirt on the window surfaces. They did a really nice job of making seamless composites.”

To evade pursuers, Wayne drives the batmobile to the top of a multi-story parking garage, blasts through a retaining wall and rockets the vehicle across adjacent rooftops. “The roof chase got a bit far-fetched,” admitted Dan Glass, “but it was done in a believable way. The batmobile was never leaping up. It was always leaping down to a lower level.”

The parking structure ascent was shot on location with the full-scale batmobile. Subsequent cuts of the vehicle vaulting from the roof featured a 1/3-scale batmobile created by Cutting Edge model builders, who adapted Corbould CAD designs to incorporate a robust radio-controlled drive system.



Alone in a cave beneath Wayne Manor, Bruce Wayne confronts a childhood fear, allowing a swarm of bats to flock around him. During preproduction, the filmmaker experimented with shooting live Egyptian fruit bats as bluescreen elements. The creatures’ erratic movements, however, led to the decision to generate all bat shots via digital animation. The Moving Picture Company – assigned most of the shots – modeled its CG creature using a high-resolution scan of a taxidermy bat. Artists then rotoscoped live bat footage, generated bat motion studies and replicated natural bat behavior through swooping flocks driven by MPC’s artificial intelligence crowd simulation software.

“We had to overbuild our miniature because the stresses were proportionally greater than on the full-scale car,” said Robbie Scott. “Our car was supposed to jump 20 feet — at which point the real car may or may not have survived, but I don’t know if the occupant would! That meant a lot of testing of the differentials and interior equipment.” The miniature was fitted with operating suspension, carbon fiber monocoque and functional details. “We had hydraulic disc brakes, forward, reverse, variable speed and steering, lights and mech-anized aerodynamic spoilers. The finished miniature was in the region of 80 pounds and measured about four feet long.” Lead modelmaker Greg Morgan oversaw construction of the miniature batmobile, as well as additional bucks for stunt sequences.

Cutting Edge also built a 1/3-scale, 80-by-30-foot rooftop set, which featured breakaway pieces built out of annealed aluminum and was dressed with pools of recent rainfall, debris and miniature newspapers. The miniature was surrounded by greenscreen. Radio control driver Philip Greeno operated the miniature batmobile from a high vantage point, affording clear views of the set, while Steve Begg’s team covered the action at rooftop level from seven cameras, some handheld, shooting at speeds between 30 and 48 frames per second to enhance scale. “We rejigged shots to camera,” noted Begg, “and Chris Nolan seemed happy with that approach, because it wasn’t set in concrete. We had a predescribed route for the batmobile, but the action around that was ad-libbed. It was more like a second-unit shoot — what you see is what we got, quite often by accident.”

For the first rooftop jump, Peter Hutchinson’s team propelled a weighted batmobile buck from a hydraulic catapult. “We discussed using wires,” said Begg, “but I felt that the ballistic trajectory would look fake. So we thought, ‘Screw this, let’s just throw it.’” The batmobile’s leap from a flat roof to a gabled, tiled roof was created with the non-radio-controlled miniature fired off a ramp. “We had a spectacular flight, but unusable crash. Then we shot another angle with the batmobile landing and skewing; and then we repositioned it for the next shot. It was an editorial effect.”

The miniature batmobile’s tail rocket was simulated by a light in the exhaust pipe. Double Negative tracked the light and composited an element of the full-scale batmobile rocket plume, shot on a turntable from a variety of angles. Double Negative also created views of Gotham architecture beyond the rooftop, generating digital matte paintings from a library of backgrounds photographed on location in Chicago.

The production planned the Chicago background shoot initially to cater to a third-act fight scene set inside a monorail public transport system that snaked around the city. “The idea was to shoot process plates as backgrounds for window views,” remarked Janek Sirrs. “Rather than shooting pre-



Wayne adopts his crime-fighter persona using military body armor developed by Wayne Enterprises as his batsuit. Costume designer Lindy Hemming consulted with prosthetic designer Nick Dudman to develop a flexible latex and neoprene batsuit. Chris Corbould’s physical effects team assisted in production of the batcape, which contained air-membrane ribs that could suddenly stiffen, holding the cape fabric taut for purposes of gliding. Nolan shot Christian Bale or stunt double Buster Reeves flown by wires in sets, on locations or against bluescreen. For shots otherwise unachievable, Double Negative generated a digital double, making frequent use of live-action reference.

selected angles, Chris wanted complete freedom to shoot handheld shots in the train; so we planned to motion track the sequence and shoot 360-degree coverage of the city to serve as backgrounds, no matter where the camera was pointing.”

The background shoot eventually served more than the monorail chase, allowing Double Negative to construct digital matte paintings and set extensions for expansive views of the city throughout the film. Backgrounds included two areas of downtown Chicago — an amphitheater-like bowl of skyscraper canyons used for the rooftop chase, and a long run of buildings used for the chase and train sequences. “We shot from the tops of buildings and from within the bowl of buildings,” said Dan Glass. “The main unit had an aerial photographic helicopter and seven stills units shooting simultaneously, recording in high detail all the faces of the buildings at night. That gave us accurate stills to construct plates using exactly the same lighting Wally Pfister used on set.” Survey equipment included General Lift’s motion control Tesselator panoramic camera system, which allowed camera operators to rapidly shoot grids of overlapping image tiles.

For city views from buildings, Double Negative employed manually-operated Canon 10D digital SLR cameras on nodal heads, mechanized to pan and tilt with a 10-percent overlap between images. For longer street-based image tile runs, Ian Menzies’ Motion Control Cameras supplied a pan/tilt motion control head mounted to the bucket of a Condor crane. Double Negative sent Kuper data from laptops to stepper motors 120 feet above using the Tesselator sequenced to shoot nine-by-nine-frame grids of images — a 50mm lens shooting a 200-degree horizontal pan and 100-degree tilt — on each side of the street. “We started at the top of La Salle Street by the Chicago River,” said Paul Franklin, “then we moved down La Salle to the Chicago Board of Trade, shooting long-bracketed exposures in 28 positions along three-quarters of a mile. It took two weeks, but we got it down to a half-hour turnaround for each setup. We ended up with more than one-and-a-quarter-million exposures.”

To catalog the vast quantity of city backgrounds, Double Negative developed ‘Superbrowser’ — an image-collating tool that allowed artists to stack and stabilize image tiles — then wove images together using ‘Stig,’ a proprietary image-stitching tool. “None of the off-the-shelf stitching tools we looked at could cope with the resolution at the bit-depth we needed,” said Franklin. “We wanted to render everything at 32-bit Open EXR, and be able to manipulate images in enormous panoramas; so we developed our own highly optimized tool with intelligent features.”

Stig assisted the creation of three styles of digitally generated backgrounds. For deep-background cityscapes, the software enabled artists to import high dynamic range source material into 16-bit color space Adobe Photoshop and project results into 3D space, before reforming imagery in Open



Christopher Nolan and production designer Nathan Crowley gave Batman’s mode of transport a radical shakedown, capitalizing on the real-world basis for Batman technology by making the batmobile a lethal all-terrain vehicle. Chris Corbould’s team scratch-built four fully operational batmobiles, one unmechanized version and an oversized interior. The vehicle, powered by a 350-horsepower Chevrolet engine, was capable of traveling 90 miles per hour and making 60-foot jumps. Mechanical features included aerodynamic flaps, armament and a pyrotechnic rear jet.

EXR. For midground buildings, image tiles could be mapped directly onto geometry using 3D projection shaders. “Our lead digital environments artist, Imery Watson, worked out such a slick way of working our 3D projection pipeline,” commented Franklin, “we christened the pipeline ‘Imeryvision.’ We used our stitched environment to provide textures for digital extensions of Chicago and the Cardington set.”

Extreme camera moves required additional projection techniques. “The Imeryvision pipeline gave us great detail at high fidelity to the original location,” said Franklin, “but it was limited if we wanted to see around the backs of buildings where textures didn’t cover. So our research and development supervisor, Oliver James, developed two killer applications. One was called ‘Photofit,’ which was a photogrammetry tool that allowed us to compare multiple angles of a piece of architecture, correspond points between images, then reconstruct architecture from that information. That fed into another tool called ‘Pertex,’ which allowed us to project textures onto geometry, then bake that into place so we could fly the camera around. We used all those techniques to digitally re-create large sections of Chicago, the Cardington set and miniatures.”

To establish Gotham’s urban layout, the art department built a 15-by-25-foot maquette with buildings three and four inches high defining the downtown sprawl, waterways, monorail and slums.

The maquette was videotaped with smoke and atmospheric lighting to suggest a dawn effect for a test shot. Double Negative used the test as reference to explore the capabilities of its digital pipeline, starting with a commercially available low-resolution architectural model of downtown Chicago. “We swapped all the buildings with buildings that we’d covered through our photogrammetry and lidar processes and a lot of hand-modeling,” commented Franklin. “Initially, it seemed quite daunting; but with our new pipeline it took our modeling artists about a month and a half to model all the large objects.” In Double Negative’s proprietary asset management system, a modelmaker could fashion one city block containing approximately 50 buildings, save the layout in a bounding box, then replicate the block on a grid derived from maps of the Gotham layout. “As we went along, we created a variety of city blocks. We had tools that allowed us to sculpt the height of buildings, defining the business district, industrial and residential areas, airport, freeways, docks — all of which had characteristics based on the layout of Chicago, New York and other cities that we used as reference.”

Buildings were textured with location source material, surrounded by digital water, populated with road, rail and water traffic, and enhanced with atmospheric effects, such as a hazy sunrise blended into a Chicago sky, shot with the sun reflecting over Lake Michigan. Viewed side-by-side with the



The Scarecrow, alter-ego of psychiatrist Jonathan Crane (Cillian Murphy), dons a sackcloth hood to torment his patients at Arkham Asylum who have been exposed to a mind-altering fear toxin. Bufo Compagnie generated hallucination effects, creating distorted perceptions of reality personalized to each victim's worst fears. To transform the Scarecrow, Bufo modeled Murphy's hooded head in 3D and used the geometry to track in varied effects, including fleshy maggots, writhing worms and flapping bats. Animated high-frequency vibrations, jump cuts and static motion blurs further added to the experimental and jarring effects.

maquette test, the results convinced Nolan to commit to a fully digital city for wide establishing shots. The digital city was also used to fill out lower-level establishing shots surrounding the Narrows, an island in the center of the city, home to Arkham Asylum and Gotham's criminal contingent. Cutting Edge constructed the Narrows island as a 40-by-80-foot, 1/12-scale miniature, designed to blend into production plates. "In Chicago," said Dan Glass, "we took the river that runs around the central business area and used the riverbank to lead us into the Narrows. We motion-tracked helicopter and ground-based plates to drive motion control photography of our Narrows miniature."

The Narrows miniature featured several hundred buildings built in three sizes up to four feet tall, all internally lit. "We built the city on light boxes and dressed buildings over the top," said Robbie Scott. "We incorporated a model of Arkham Asylum based on the exterior location in Mill Hill, London, and based other buildings on the set at Cardington. We detailed them with window moldings, etched-brass TV aerials and a lot of cabling between the buildings to make it all flow together. It was about a 12-week build." The Narrows miniature required an average of 12 Milo motion control passes, including beauty, fill and practical lighting, a matte pass and several atmospheric smoke layers. Double Negative compositors averaged takes to reduce smoke motion and added 2D and 3D details, including plumes of steam, room interiors, background buildings, roadways, traffic, bridges and CG water.

Double Negative created daytime city views using Vistavision plates of location structures such as the Chicago Board of Trade, which served as the basis for the 900-foot art deco Wayne Tower. Daylight was simulated using digital lighting cards of high dynamic range location imagery placed around the CG model. "We wanted to avoid the flat look of CG lighting that is usually achieved with spherical reflection maps and diffusion," stated sequence supervisor Graham Jack. "HDRI lighting cards gave our lighting a complexity that could not be achieved even with hundreds of CG spotlights. We obtained another layer of complexity by rendering an indirect diffuse lighting pass on buildings, and rendered that as a separate pass."

Escaping Gotham City, the batmobile returns to its safe haven in a cave beneath Wayne Manor, leaping a gorge and plummeting through a waterfall. Wayne Manor exteriors were filmed with the full-scale batmobile racing through the grounds of Hatfield House in Hertfordshire — site of Tim Burton's Wayne Manor — while the approach to the batcave was a miniature element filmed on the backlot at Leavesden Studios.

The miniature waterfall was realized at 1/3 scale, and determined the considerable size of miniatures used throughout the film. "We felt that 1/3 scale was manageable and would achieve



The dark underbelly of Gotham City is housed in a festering slum known as the Narrows. Cutting Edge constructed the island locale as a 40-by-80-foot miniature, which featured several hundred internally lit buildings dressed with window moldings, forests of television antennae, electrical cabling and a 1/12-scale model of Arkham Asylum. The miniature blended into live-action plates of Chicago's central business district, bridging the natural riverbank. Double Negative designed motion control camera moves, blended miniature and full-scale elements, and enhanced shots with digital smoke plumes, shadow patterns, light sources and a veil of rain and mist.

more believable scaling effects on the water,” recalled Steve Begg. “Even at 25 feet high, it still didn’t scale easily.” Chris Corbould’s team assisted the waterfall effect — rigging compressed air jets and fantail water outlets to atomize the water — then catapulted a batmobile buck through the falls. The leap required some digital enhancement, since the vehicle looked most realistic at 96 frames per second, but the waterfall looked best at 60 frames per second. Begg shot two passes, at the two different frame rates, then Double Negative split them together.

For the batmobile’s entry into the batcave through the reverse side of the falls, the physical effects team engineered a full-scale waterfall and flowing river inside a Shepperton stage set and launched a full-scale batmobile — minus engine, gearbox and driver — from a high-pressure nitrogen catapult.

Inside the batcave were flocks of bats. The production first explored the possibility of employing live, trained Egyptian fruit bats, but the creatures proved uncooperative. “We shot a bluescreen test in keeping with the idea of doing everything practically,” stated Janek Sirrs, “but we found that it was almost impossible to follow a group of bats with a camera. For the number of shots and the flexibility we needed, there was no other choice but to animate them.”

The bluescreen bat test, though a failure, served as reference for a proof-of-concept CG bat test generated by The Moving Picture Company. “The idea was to 3D-rotoscope the real motions of bats in flight,” related Dan Glass. “For every bat scene, we also shot lighting reference with a high dynamic range chrome ball and a stuffed bat on a stick.”

A freeze-dried bat and high-resolution geometry of a taxidermy bat scanned by XYZ in Canada aided construction of a 3D bat. “The gray-scale model served as a starting point for surfaces,” related MPC visual effects supervisor Rudi Holzapfel. “We built a skeleton rig and added muscles to help the wings catch the wind and bulge when they flapped.” Rendered full screen, with fur and glinting eyes, and animated to match a closeup of a live bat roosting and taking flight, the test convinced production of CG bat viability. Animators then concentrated on bat behavior for scenes of bats swirling in flocks.



Batman in his batmobile faces off with Gotham City police atop a high-rise parking garage, then escapes by blasting through a wall and driving off the building. Nolan set up the stunt with the full-size batmobile on a parking structure in Chicago. The wall detonation and subsequent cuts featured a 1/3-scale radio-controlled batmobile, built by Cutting Edge and filmed by miniature effects supervisor Steve Begg on a rooftop set backed by greenscreen. Double Negative combined the miniature with a Chicago background plate, digitally enhanced the lower floor of the miniature garage, added lens flares and chromatic aberrations, and a hovering CG helicopter.



The batmobile crash-lands on a lower rooftop, then vaults onto an adjacent gabled roof, shattering roof tiles. Cutting Edge constructed a 1/3-scale rooftop set featuring breakaway pieces. Begg’s team covered the action from a variety of angles using combinations of the 80-pound radio-controlled miniature traveling at high velocity and a similarly weighty non-radio-controlled version fired from a ramp. Double Negative enhanced the batmobile’s impact with digital debris and added a 3D Gotham City background, complete with moving reflections and a freeway model with speeding traffic.

Swarming scenes made use of MPC's proprietary Artificial Life Crowd Engine, A.ICE, developed for crowd simulations in *Troy* and further used in *Alexander* and *Kingdom of Heaven*. "Whereas A.ICE had previously sampled motion capture for horses and soldiers," commented Holzapfel, "we used 3D roto of the footage that Janek and Dan had shot, as well as footage we shot at a bat sanctuary, to build a motion library of clips — bats landing, taking off, roosting, flying straight, flying in a curve, accelerating, diving." Animators utilized lidar geometry of sets to define flight paths through scenes, describing sometimes as many as a dozen 'cords' of action. A.ICE populated cords with bats and sampled motion clips, blending one style of behavior to the next, and applied physical stimuli of wind that buffeted the flock.

Bats are first seen hurtling at the young Bruce Wayne (Gus Lewis), after he has fallen down an abandoned well. Blasts of wind on set and flickering lighting effects helped simulate bat interaction, which MPC animated with procedural variation, scaling bats with varieties of weights to make them more or less maneuverable. Wayne confronts his childhood phobia of the creatures by returning to the cave as an adult, allowing a vortex of 25,000 bats to swarm around him. "Christopher Nolan wanted bats to create a tornado around Bruce Wayne," explained Holzapfel. "As they fly around him, Bruce just stands there. As he overcomes his fear, the bats become less chaotic, as if they both know he's there to stay."

A complex lighting scheme was required for the Arkham Asylum rescue sequence, where Wayne activates an electronic homing beacon that causes thousands of bats to swoop into the building to cover his escape past a cordon of police officers. Bats smash through windows — live footage enhanced with 3D animation of exploding glass — then surround *Batman* and police sergeant Gordon (Gary Oldman) as they walk through asylum corridors. "We created 3D roto geometry for all of the characters close to camera," explained Holzapfel. "We then used an in-house tool to export Maya Live into Shake and set 3D lights to relight geometry. Some of the bats flew very close to camera, sometimes filling half a frame, quite soft and motion-blurred, but showing a lot of detail in their mottled fur, with subsurface scattering in the skin, nose and ears."

Buf Compagnie produced a flock of bats for the opening moments of the film, in which bats swarm to form a giant, dreamlike cloud of flapping creatures. The shot made use of a model derived from the XYZ Egyptian fruit bat scan, rigged for animation using technology developed at Buf for crowd simulations in *Alexander* — a handcrafted process that sampled banks of keyframe animation, intermingled varieties of models, sizes and colors of bats, and directed the flow into a prescribed volume, rendered in mental ray.

Buf's primary task for the production involved a series of hallucinations for scenes in which Jonathan Crane dons a sackcloth hood and poses as 'the Scarecrow,' using a mind-altering fear toxin to terrorize the population of Gotham. For scenes with Crane in *Scarecrow* guise, the production fabricated a ragged fabric hood and a demonic latex prosthetic mask. Nolan ultimately only used the sackcloth version, with digital enhancement. "Chris didn't want the Scarecrow to be too much like a horror movie effect," commented Janek Sirrs. "He wanted to see just a glimpse of an effect and then cut away."

The fear toxin gas, a physical effect, causes hallucinations when blown into victims' faces. "Our visual effects were perceptual effects of the victims hallucinating," said Buaf visual effects supervisor Stéphane Ceretti, "becoming psychotic with their different perceptions of reality. We had different styles of hallucinations, each person seeing the *Scarecrow* in different ways, based on their worst fears. In one scene, we animated worms appearing on the *Scarecrow*'s face; in another, *Batman* sees a bat appear out of the *Scarecrow*'s mouth to reflect his childhood fear of bats."

To transform the *Scarecrow*, Buaf modeled Cillian Murphy's hooded head in 3D and used the geometry to track effects to the plate. "There were scars on the *Scarecrow*'s face," said Ceretti. "We added fleshy maggots crawling inside the scars and inside the mouth utilizing hand-animated worm animation projected onto the face." The bat crawling from the *Scarecrow*'s mouth required a special animation rig that allowed the wings to fold inside the constricting space before spreading out and flapping, followed by ten more bats that burst from the character's mouth and eyeholes.

All hallucinations included digitally-animated high-frequency vibrations. "We gave characters white glowing eyes and no pupils," remarked Ceretti, "then we added vibrations, jump cuts and static motion blurs to enhance the jarring effect, blending transitions with motion blur. We worked very closely with editorial and sound effects to establish timings. It was a very creative and experimental process."

After experiencing the fear toxin firsthand, *Batman* turns the tables on the *Scarecrow*, infecting his adversary with the hallucinogen and taking on the appearance of a ferocious demon man-bat. Nick Dudman's team sculpted prosthetic appliances for Christian Bale to wear in demon form. Molded and cast in black-tinted foam latex, the appliance covered Bale's head and upper body. To animate the hallucination in six shots, Buaf conducted digital



Gotham City's monorail, racing at high speed 150 feet above the streets, is the principal setting for the film's action finale. For interior scenes, production built two full-scale monorail cars, shot on a gimbal and backed by greenscreen. Double Negative digitally created monorail exteriors for shots of the train snaking through the city. Skyscraper canyons were derived from a vast digital database of Chicago surface textures, projected and mapped to 3D geometry. Monorail cars were animated with articulated suspension, mapped with textures from Chicago El-train cars and lit using lens distortion and flare patterns derived from 1950s-vintage lenses employed by the production.



effects experiments using a clean background plate, texture photographs and a cyberscan of the makeup. “We darkened all the features so the demon looked intensely black,” said Ceretti, “painting out the whites of Christian’s eyes and the pink inside his mouth. Then, as he speaks, he spilled a dark liquid goop, like black magma.” Buf generated goop as a fluid simulation, tracked to Bale’s face and lips. “We used displacement mapping to make it read, slowly flowing out, being very careful to match the density of the black levels in the plate.”

The train is derailed when the batmobile shoots out one of the monorail’s support towers. The physical effects crew staged a full-scale tower collapse on the set. Cutting Edge constructed a sizable portion of the street and monorail set as a 50-foot-tall miniature, using malleable aluminum and plastic rails and girders capable of buckling. Monorail structures were supported by steel wires and released by pyrotechnic charges, their descent controlled by effects rigging. A hydraulic ram propelled breakaway miniature train cars along 50 feet of track.

The movie climaxes on board the Gotham City monorail, from which members of a sinister cult attempt to spread the fear toxin across Gotham using a prototype military weapon — the ‘focused emitter’ — that vaporizes the city’s infected water supply. The physical effects crew plumbed giant plumes of steam through the Gotham City set at Cardington, triggered to fire in the wake of the train passing above. “We used four massive steam generators the size of articulated trailers,” stated Chris Corbould. “When these things went off, every manhole cover flew up in the air on a big column of steam, fire hydrants blew, air conditioning units went up, steam flew horizontally, diagonally, vertically, going up 100 feet. It was total mayhem. Then, after we’d done a run and all the steam had gathered in the roof, it would begin to fall like rain. We created our own mini-ecosystem!”

Nolan shot monorail interiors on a separate set, using two 40-foot carriages on a gimbal to simulate train motion, filmed before greenscreen. Wide exterior views of the train passing through the city were generated digitally at Double Negative, using backgrounds filmed in Chicago. “We didn’t have time to shoot specific plates on location for the monorail chase,” recalled Janek Sirrs, “so we repurposed material shot for window views seen from inside the monorail and used those to generate full-on city views. All views of the train racing down the street were 100-percent synthetic.”

To provide reference for digital train exteriors, the Chicago Transit Authority gave Paul Franklin and Double Negative producer Hal Couzens access to El trains and shunted carriages around to different lighting conditions. Double Negative CG supervisor Peter Bebb also spent a day shooting reference of Hungerford Bridge and Victoria Station in London. Live-action texture reference was applied to a 3D model of the train, detailed with articulated suspension, tracks and towers, signal lights and anti-vandal fences.

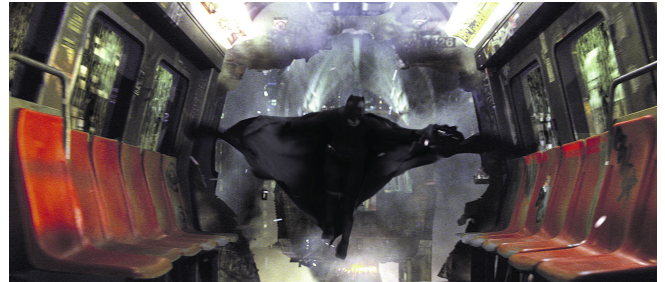
During a climactic fight, the train is seen passing through columns of steam, generated digitally using Double Negative’s DNB volume-rendering tool, with animation driven by Maya fluid dynamics matched to full-scale effects. For closeups of *Batman* dangling beneath the speeding train, Buster Reeves performed hanging beneath a 300-foot-long stunt rig in Cardington, pursued by a remotely operated camera suspended from cables. Wide shots employed the digital *Batman* and — for a scene conceived in postproduction — a digital street and batmobile. “We built a low-rez digital batmobile for previz and miniature motion control programming,” stated Paul Franklin. “When we realized there were a couple of places we might need a digital batmobile, we uprezed the model as a

contingency, using scans of the vehicle taken as prop reference by Plowman Craven Associates.” The CG vehicle was used in three shots: two of the batmobile jumping an up-raised bridge into the Narrows, and one of its overtaking the train during the monorail chase. “Sequence supervisor Alex Wuttke created an entirely digital shot, seen from the monorail looking down into the street. It had a fully-digital street populated with cars, newspaper stands, traffic lights, flying manhole covers and a CG batmobile turning a corner.”

Sergeant Gordon, driving the batmobile, prevents the train from crashing into the Gotham Water Board in Wayne Tower by shooting out the leg of a monorail tower. The scene was achieved through a combination of full-scale, digital and miniature effects. Chris Corbould’s team created an 80-foot-tall monorail support on the Cardington set, rigged to collapse on cue. Double Negative created Wayne Tower and Wayne Station as digital structures blended into a virtual re-creation of Chicago’s La Salle Street. Cutting Edge constructed the last four buildings in the street as a 1/6-scale miniature that stood 50 feet tall. “The miniature monorail set was colossal,” asserted Steve Begg. “That was necessary because the crash had to be pretty awe-inspiring. Pete Hutchinson handled all the pyrotechnics, and Chris Corbould handled the mechanics and hydraulic engineering. We had a great time destroying the hell out of that model.”

Director of miniature photography Peter Talbot lit the monorail set using miniature Kino Flo lighting rigs to simulate realistic lighting along the street, inside the train and buildings. The monorail collapse was designed as a gravity gag, rigged to fall under its own weight and filmed at 80 frames per second. Modelmakers built rails and girders out of malleable aluminum and plastic capable of buckling at realistic scale. Monorail structures were supported by steel wires and released by pyrotechnic charges, with their descent controlled by effects rigging. “One of the bigger towers was a huge metal construction with an effects rig built into it,” said Robbie Scott. “That had to tilt and crash into a building. We dropped the rail on descenders built into the set. The train crashed through the upper surface. Then we built another set for underground shots, pulling the carriages through pillars under the roadway.”

Scott’s team built three breakaway aluminum train carriages, which Chris Corbould’s crew propelled along 50 feet of track using a hydraulic ram with compounded pulleys and steel cable. “The train followed a flight path relative to the laws of Newtonian physics,” said Begg. “We didn’t have any real control there; so Chris did a lot of testing beforehand, throwing suitably weighted objects through the set. The train hit the base of the station house and crashed its way down through the building. We were given carte blanche by Chris Nolan to blow the crap out of that. We had it smash through an underground car park and crash through cars and concrete blocks before it impacted on a wall and blew up.” Begg covered the action in a series of shots, as a hydraulic winch hauled the train



As the monorail topples, the car containing Batman and his nemesis is torn in half. The Dark Knight escapes by extending his cape and flying backward out of the monorail car as its support structure crashes to the street. The production filmed a stunt performer falling backward from the full-scale train interior on the greenscreen set. Double Negative created a digital-double Batman to blend into the stunt performance, then modeled and inserted the portion of the train car tearing away, and added a digital Gotham City, monorail cars and tracks receding in the background.

through the set at speeds approximating 30 miles an hour. “We used multiple cameras, with spherical lenses to get depth of field. Some cameras were locked off, some remotely operated. We did tracking shots following the train using rope or bungees attached to a pulley and manually pulled the camera dolly along, trying to match the speed of the train. Even when the train overtook the camera, we managed to get some interesting shots.”

The emphasis on physics and real-world reference informed all aspects of the production of *Batman Begins*, from character and story to visual effects and final color timing — completed without a digital intermediate to preserve the film’s earthy color scheme. “A great deal of the location photography was shot with available light,” remarked Dan Glass. “There was augmentation here and there, but the mixture of color temperatures was radically different from what might be expected in a comic book movie. Chris Nolan wanted to create a world that audiences could relate to, because *Batman* is the most understandable of superheroes. He is not an infinitely gifted entity — he is human. Visual effects had to serve as an augmentation, without detracting from that, and I think the film was very successful in that regard. Even when large parts of the image were CGI, the originating camera moves had a very naturalistic feel and weight.”

Batman Begins’ considerable technological achievements were ultimately balanced by the filmmakers’ grassroots approach to revitalizing the 66-year-old legend. “This was starting over,” asserted Janek Sirrs, “and it was a question of restraint. Nobody wants a movie to be nonstop action all the time. It should be a rollercoaster ride of peaks and troughs, no matter what the medium is. If you have an engrossing story, and if the performances are great, format shouldn’t matter. You can’t tart that up with eye candy.”

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